TRANSACTIONS

OF THE

AMERICAN SOCIETY

OF

MECHANICAL ENGINEERS.

VOL. XXIV.

XLVIth Meeting, New York, N. Y., 1902.
XLVIIth Meeting, Saratoga, N. Y., 1903.

NEW YORK CITY:
PUBLISHED BY THE SOCIETY,
From the Library Building,
No. 12 West 31st Street.
1903.

OFFICERS

OF THE

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

1902–1903,

FORMING THE STATUTORY COUNCIL.

PRESIDENT.

JAMES M. DODGE.......................................Philadelphia, Pa.

VICE-PRESIDENTS.

WILFRED M. LEWIS.......................................Philadelphia, Pa.
M. E. COOLEY.......................................Ann Arbor, Mich.
M. P. HIGGINS.......................................Worcester, Mass.
Terms expire at Annual Meeting of 1903.

F. H. DANIELS.......................................Worcester, Mass.
JAMES CHRISTIE.......................................Philadelphia, Pa.
JOHN R. FREEMAN.......................................Providence, R. I.
Terms expire at Annual Meeting of 1904.

MANAGERS.

W. F. M. GOSS.......................................Lafayette, Ind.
DE COURCY MAY.......................................Camden, N. J.
D. S. JACOBUS.......................................Hoboken, N. J.
Terms expire at Annual Meeting of 1903.

R. S. MOORE.......................................San Francisco, Cal.
H. A. GILLIS.......................................Richmond, Va.
CHAS. H. CORBETT.......................................Brooklyn, N. Y.
Terms expire at Annual Meeting of 1904.

R. C. MCKINNEY.......................................New York, N. Y.
S. S. WEBBER.......................................Trenton, N. J.
NEWELL SANDERS.......................................Chattanooga, Tenn.
Terms expire at Annual Meeting of 1905.

TREASURER.

WM. H. WILEY.......................................Nos. 43-45 East 19th St., New York, N. Y.

SECRETARY.

PROF. F. R. HUTTON.......................................No. 12 West 31st St., New York, N. Y.

HONORARY COUNCILLORS.

PAST PRESIDENTS OF THE SOCIETY.

R. H. THURSTON	1880—1882	Ithaca, N. Y.
E. D. LEAVITT	1882—1883	Cambridge, Mass.
JOHN E. SWEET	1883—1884	Syracuse, N. Y.
COLEMAN SELLERS	1885—1886	Philadelphia, Pa
HENRY R. TOWNE	1888—1889	Stamford, Conn.
OBERLIN SMITH	1889—1890	Bridgeton, N. J.
ROBERT W. HUNT	1890—1891	Chicago, Ill.
CHARLES H. LORING	1891—1892	Brooklyn, N. Y.
CHARLES E. BILLINGS*	1895	Hartford, Conn.
JOHN FRITZ	1895—1896	Bethlehem, Pa.
WORCESTER R. WARNER	1896—1897	Cleveland, O.
CHARLES WALLACE HUNT	1897—1898	New York City.
GEORGE W. MELVILLE	1898—1899	Washington, D. C.
CHARLES H. MORGAN	1899—1900	Worcester, Mass.
S. T. WELLMAN	1900—1901	Cleveland, O.
EDWIN REYNOLDS	1901—1902	Milwaukee, Wis.

[NOTE.—The former Presidents of the Society are members of the Council for life or during their retention of active membership in the Society.]

* Unexpired term of E. F. C. Davis.

NOTE.

The considerable bulk of the volume of Transactions has induced the Publication Committee to direct the insertion of a summary of the Society membership in place of the complete list of members which was published in the earlier volumes. The summary attaching to this issue is that which appears in the catalogue of the Society issued with corrections to July 1st, 1903. Reference for the complete list should be made to the twenty-fourth catalogue (second edition).

The summary is as follows :

FOREIGN COUNTRIES.

	Membership.		Membership.
Africa	19	Holland	1
Australia	4	India	2
Belgium	3	Jamaica, W. I.	1
Canada	30	Japan	6
Central America	1	Mexico	6
China	2	Norway	1
Cuba	2	Russia	4
France	7	South America	7
Germany	7	Sweden	4
Great Britain (England)	48	Switzerland	1
Great Britain (Scotland)	3		

Total foreign membership 159

UNITED STATES.

	Membership.		Membership.
Alabama	6	Nebraska	2
Alaska	1	New Hampshire	15
Arkansas	2	New Jersey	127
California	29	New Mexico	1
Colorado	23	New York	786
Connecticut	103	North Carolina	6
Delaware	15	North Dakota	1
District of Columbia	30	Ohio	172
Georgia	9	Oklahoma	1
Hawaii	1	Oregon	4
Illinois	156	Pennsylvania	354
Indiana	30	Porto Rico	1
Iowa	5	Rhode Island	49
Kansas	8	South Carolina	3
Kentucky	8	Tennessee	3
Louisiana	10	Texas	6
Maine	13	Utah	3
Maryland	83	Vermont	10
Massachusetts	285	Virginia	28
Michigan	61	Washington	5
Minnesota	12	West Virginia	6
Missouri	37	Wisconsin	49
Montana	11	Wyoming	1

Total membership in the United States........2,411

Total foreign membership	159
Total membership in United States	2,411
Present address unknown *	3
Total membership	2,573

SUMMARY OF MEMBERSHIP BY GRADES.

Honorary members	18
Members	1,750
Associate members	202
Junior members	603
Total membership	2,573

* These are J. M. Ewen, C. R. Johnston and J. W. Snyder, and if any member knows their present addresses, he will confer a favor by advising the Secretary of them.

RULES OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

ART. 1. The objects of the AMERICAN SOCIETY OF MECHANICAL ENGINEERS are to promote the Arts and Sciences connected with Engineering and Mechanical Construction, by means of meetings for social intercourse and the reading and discussion of professional papers, and to circulate, by means of publication among its members, the information thus obtained.

ART. 2. All persons connected with engineering may be eligible for admission into the Society.

ART. 3. The Society shall consist of Honorary Members, Members, Associates, and Juniors.

ART. 4. Honorary Members, not exceeding twenty-five in number, may be elected. They must be persons of acknowledged professional eminence.

ART. 5. To be eligible as a Member, the candidate must be not less than thirty years of age, and must have been so connected with engineering as to be competent as a designer or as a constructor, or to take responsible charge of work in his department, or he must have served as a teacher of engineering for more than five years.

NOTE.—The Rules of the Society, adopted in 1880, were in force until 1884, when they received general revision by a careful committee, whose report, distributed by letter ballot, was adopted November 5, 1884. In December, 1894, a similar extensive revision was made under direction of the Council, and the present rules are those of 1894. They include the amendments made in 1889, 1891, 1893, and 1898, which were the only changes since the revision of 1884.

Art. 6. To be eligible as an Associate the candidate must be not less than twenty-six years of age, and must have the other qualifications of a member; or he shall have been so connected with engineering as to be competent to take charge of work, and to coöperate with engineers.

Art. 7. To be eligible as a Junior, the candidate must have had such engineering experience as will enable him to fill a responsible position, or he must be a graduate of an engineering school.

Art. 8. All Honorary Members, Members, and Associates shall be equally entitled to the privileges of membership. Juniors shall not be entitled to vote, nor to be officers of the Society.

Art. 9. Nominees for Honorary Membership must be proposed by at least five Members who are not officers of the Society. References shall not be required of a nominee for Honorary Membership, but the grounds upon which the application is made must be fully set forth in writing and signed by the proposers.

Art. 10. A candidate for admission to the Society, as a Member or as an Associate, must make an application on a form to be prepared by the Council, which shall contain a written statement giving a complete account of his engineering experience and an agreement that he will, if elected, conform to the laws, rules, and requirements of the Society. He must refer to at least five Members or Associates to whom he is personally known. A candidate for admission to the Society as a Junior must make an application on the same form, and refer to not less than three Members or Associates to whom he is personally known.

Applications for membership from engineers who are not resident in the United States and Canada, and who may be so situated as not to be personally known to five Members of the Society, as required in the foregoing paragraph, may be recommended for ballot by five Members of the Council, after sufficient evidence has been secured which shall show that in their opinion the applicant is worthy of admission to the grade which he seeks.

Art. 11. The referees for each candidate for admission to the Society shall be requested to make a confidential communication on a form to be prepared by the Council, setting forth in detail such information, personally known by the referee, as shall enable the Council to arrive at a proper estimate of the eligibility of the candidate for admission to the Society. Such confidential communications shall be destroyed by the Secretary as soon as the vote has been officially declared.

ART. 12. All applications for membership must be presented to the Council, and this body shall consider each application, assigning to each, with the applicant's consent, the grade in the Society to which, in its opinion, his qualifications entitle him. The names of those candidates recommended for election by the Society shall be immediately printed on a ballot, and the ballot mailed at once by the Secretary to each voting member of the Society. Persons desiring to change their grade of membership from junior to associate or from associate to member shall make an application in the same manner and on the same form as that required for a new applicant.

ART. 13. A member entitled to vote may leave the name of any candidate on the ballot untouched to vote in favor of the admission of the candidate to the Society, or he may erase the name to vote against it. He shall enclose the ballot so approved by him in a sealed blank envelope, and enclose this envelope in a second envelope, on which he shall write his name, and mail the same to the Secretary of the Society. A ballot without such endorsement shall be rejected as defective. The rejection of a candidate by seven voters shall defeat his election.

ART. 14. The aforesaid envelopes containing the ballots shall be opened by the Council, at any meeting thereof, and the names of those elected shall be announced in the next meeting of the Society. The names of applicants not elected shall not be announced, nor recorded in the proceedings.

ART. 15. Endorsers of any applicant not elected may, within three months after such failure to be elected, lay before the Council written evidence that an error was then made. The Council may then, by a three-fourths vote, order another similar ballot by the Society, in which case thirteen negative votes shall be required to defeat the candidate.

ART. 16. Honorary members shall be elected by the unanimous vote of the Council, through a letter ballot, not less than sixty days subsequent to the proposal, a notice of which proposed election shall have been mailed at once by the Secretary to each member of the Council.

ART. 17. Each person elected, excepting honorary members, must subscribe to the Rules of the Society, and pay the initiation fee before he can receive a certificate entitling him to the rights and privileges of the Society, and to wear the emblem appropriate to his grade. If this payment is not made within six months of the election, the same shall be void, unless the time is extended by the Council. The emblems of each grade of membership shall be worn by those only who belong to that grade.

ART. 18. The initiation fee of a member or an associate shall be twenty-five dollars, and the annual dues shall be fifteen dollars, payable in advance. The initiation fee of a junior shall be fifteen dollars, and his annual dues ten dollars, payable in advance. A junior being promoted to any other grade of membership shall pay an additional initiation fee of ten dollars. Any member or associate may become a Life Member in the same grade, by the payment of two hundred dollars at one time, and shall not be liable thereafter to annual dues.

The Council shall have the power, for special reasons, by unanimous vote, through a letter ballot, to admit to life membership, without the payment of the sum above named, such person as for a long term of years has been a member or an associate, when such a procedure would in its judgment be for the best interests of the Society; *provided*, that notice of such action shall have been given at a previous meeting of the Council.

ART. 19. Any member of the Society in arrears may, at the discretion of the Council, be deprived of the publications of the Society, or, when in arrears for one year, he may be stricken from the list of members. Such person may be restored to the privileges of membership by the Council on payment of all arrears.

ART. 20. The affairs of the Society shall be managed by a Council, consisting of a President, six Vice-Presidents, nine Managers, and a Treasurer, who shall also be the Trustees of the Society.

All past (ex) Presidents of the Society, while they retain their membership therein, shall be known as Honorary Councillors, and shall be entitled to receive notices of all meetings of the Council and may take part in any of its deliberations; they shall be entitled to vote upon all questions except such as affect the legal rights or obligations of the Society or its members.

ART. 21. The members of the Council shall be elected from among the members and associates of the Society at the annual meetings, and shall hold office as follows:

The President and the Treasurer for one year; and no person shall be eligible for immediate re-election as President who shall have held that office for two consecutive years; the Vice-Presidents for two years, and the Managers for three years; and no Vice-President or Manager shall be eligible for immediate re-election to the same office at the expiration of the term for which he was elected.

ART. 22. A Secretary, who shall be a member of the Society, shall be appointed for one year by a majority of the members of the Council at its first meeting after the annual election, or as soon thereafter as the votes of a majority of the members of the Council can be secured for a candidate. The Secretary may be removed by a vote of twelve members of the Council, at any time after one month's notice has been given him by a majority of its members to show cause why he should not be removed, and he has been heard to that effect. The Secretary may take part in any of the deliberations of the Council, but shall not have a vote therein. His salary shall be fixed for the time he is appointed by a majority vote of the Council.

ART. 23. At each annual meeting, a President, three Vice-Presidents, three Managers, and a Treasurer shall be elected, and the term of office of each shall continue until the end of the meeting at which their successors are elected.

ART. 24. The duties of all officers shall be such as usually pertain to their offices or may be delegated to them by the Council or by the Society. The Council may, in its discretion, require bonds to be given by the Treasurer.

ART. 25. The Council may, by vote of a majority of all its members, declare the place of any officer vacant, on his failure for one year, from inability or otherwise, to attend the Council meetings, or to perform the duties of his office. All such vacancies and those occurring by death or resignation shall be filled by the appointment of the Council, and any person so appointed shall hold office for the remainder of the term for which his predecessor was elected or appointed; *provided*, that the said appointment shall not render him ineligible at the next annual meeting.

ART. 26. Five members of the Council shall constitute a quorum. Members of the Council absent from a meeting may vote by letter upon subjects stated in the call for the meeting, said vote to be deposited with the Secretary.

ART. 27. The President on assuming office shall appoint a Finance Committee and a Publication Committee and a Library Committee of five members each. The appointment of two members of each Committee shall expire at the end of each year. The Secretary shall, *ex officio*, be a member of all three committees.

ART. 28. The Finance Committee shall have power to order all ordinary or current expenditures, and shall audit all bills therefor. No bill shall be paid except upon their audit. When special appropriations are ordered by the Society, they shall not take effect until they have been referred to the Council and Finance Committee in conference.

ART. 29. It shall be the duty of the Publication Committee to receive all papers contributed, and to decide upon which papers or parts of the same shall be presented at the professional meetings of the Society. They shall see that all editorial revisions of the proceedings, papers, discussions, and reports are made; and to decide what parts of the same shall be published in the proceedings of the Society. The Council may, at its discretion, revise any action of the Publication Committee.

ART. 30. It shall be the duty of the Library Committee to take charge of the collection of all material for the Library of the Society, and to supervise all regulations for its use.

ART. 31. At the regular meeting preceding the annual meeting a Nominating Committee of five members, not officers of the Society, shall be appointed, and this committee shall, at least thirty days before the annual meeting, send to the Secretary the names of nominees for the offices falling vacant under the rules. In addition to such regularly appointed committee, any other five members or associates, not in arrears, may constitute an independent Nominating Committee, and may present to the Secretary, at least thirty days before the annual meeting, all the names of such candidates as they may select. All the names of such independent nominees shall be placed upon the ballot list, with nothing to distinguish them from the nominees of the regular committee, and the Secretary shall at once mail the said list of names to each member and associate in the form of a letter ballot, it being understood that the assent of the nominees shall have been secured in all cases.

ART. 32. In the election of Vice-Presidents, each member and associate may cast as many votes as there are Vice-Presidents to be elected. He may give all these votes to one candidate, or distribute them among more, as he chooses. Managers shall be voted for in the same way.

ART. 33. Any member or associate entitled to vote may vote by retaining or changing the names on said list, leaving names not exceeding in number the officers to be elected, and returning the list to the Secretary—such ballot enclosed in two envelopes, the inner one to be blank and the outer one to be endorsed by the voter. No member or associate in arrears since the last annual meeting shall be allowed to vote until said arrears shall have been paid.

ART. 34. The said blank envelopes shall be opened by tellers at the annual meeting, and the person who shall have received the greatest number of votes for the several offices shall be declared elected.

MEETINGS.

ART. 35. The annual meeting of the Society shall be held on the first Tuesday in December of each year, in the City of New York, unless otherwise ordered, at which a report of proceedings and an abstract of the accounts shall be furnished by the Council. The Council may change the place of the annual meeting, and shall, in that case, give timely notice to members and associates.

ART. 36. Other regular meetings of the Society shall be held in each year at such time and place as the Council may appoint. At least thirty days' notice of all meetings shall be mailed by the Secretary to members, honorary members, associates, and juniors.

ART. 37. Special meetings may be called whenever the Council may see fit; and the Secretary shall call a special meeting at the written request of twenty or more members. The notices for special meetings shall state the business to be transacted, and no other shall be entertained.

ART. 38. Any member, honorary member, or associate, may introduce a stranger to any meeting; but the latter shall not take part in the proceedings without the consent of the meeting.

ART. 39. Every question which shall come before the Society shall be decided, unless otherwise provided by these rules, by the votes of a majority of the members and associates present, provided there is a quorum.

ART. 40. At any regular meeting of the Society thirteen or more members and associates shall constitute a quorum.

ART. 41. Unless otherwise ordered, papers shall be read in the order in which their text is received by the Secretary. Before any paper appears in the *Transactions* of the Society, a copy of the paper shall be sent to the author, and, so far as possible, a copy of the reported discussion shall be sent to every member who took part in the same, with requests that attention shall be called to any errors therein.

ART. 42. The Society shall claim no exclusive copyright in papers read at its meetings, nor in reports of discussions, except in the matter of official publication with the Society's imprint, as its *Transactions*. The Secretary shall have sole possession of papers between the time of their acceptance by the Publication Committee and their reading, together with the drawings illustrating the same; and at the time of such reading, or as soon thereafter as practicable, he shall cause to be printed, with the authors' consent, copies of such papers, "subject to revision," with such illustrations as are needed for the *Transactions*, for distribution to the members and for the use of technical newspapers, American and foreign, which may desire to reprint them in whole or in part. The policy of the Society in this matter shall be to give papers read before it the widest circulation possible, with the view of making the work of the Society known, encouraging mechanical progress, and extending the professional reputation of its members.

ART. 43. The author of each paper read before the Society shall be entitled to twelve copies, if printed, for his own use, and all members shall have the right to order any number of reprints of papers at a cost to cover paper and printing; *provided*, that said copies are not intended for sale.

ART. 44. The Society is not, as a body, responsible for the statements of fact or opinion advanced in papers or discussions, at its meetings; and it is understood that papers and discussions should not include matters relating to politics or purely to trade.

ART. 45. These rules may be amended, at any annual meeting, by a two-thirds vote of the members present; *provided*, that written notice of the proposed amendment shall have been given at a previous meeting.

CONTENTS OF VOLUME XXIV.

LIST OF ILLUSTRATIONS.

PAPERS

OF THE

NEW YORK MEETING

(XLVIth)

OF THE

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

DECEMBER 2d TO 5th, 1902.

BEING ALSO THE TWENTY-THIRD ANNUAL MEETING OF THE SOCIETY.

No. 954.

PROCEEDINGS

OF THE

NEW YORK MEETING

(XLVIth)

OF THE

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

December 2d to 5th, 1902.

THE twenty-third annual meeting of the Society was held in the City of New York, during the first week of December, 1902. The Society was unfortunate for this meeting, by reason of the absence from his post of President Edwin Reynolds, who had been debarred from active duty in the early autumn by ill health. The Chair was taken during the sessions by the senior Vice-President, Arthur M. Waitt, who presided at all sessions.

The increasing growth of the Society and the interest which was expected to attach to certain discussions at the meeting, induced the Council to arrange to hold only the opening session on Tuesday evening, and the closing session on Friday morning, in the cozy auditorium of the Society House at 12 West Thirty-first Street. The sessions on Wednesday and Thursday were held in the banquet hall of the Sturtevant House on Broadway and Twenty-ninth Street. The luncheons served to their guests by the New York members on Wednesday and Thursday were also served in a room adjoining the room in which the sessions were held. The numbers in attendance proved that the decision of the Council had been eminently wise.

The opening session was called to order at 8.30 P. M. in the Society House, by Vice-President Waitt, who called on the Secretary to read the letter from President Reynolds. The Chair then asked the preference of the meeting in the matter of enforcing with some insistence the rules concerning the presentation of papers by abstract and a curtailment of the oral debate within the limit of five minutes. It was on motion decided that these rules should be adhered to during the meeting.

The Chair appointed, under the provisions of Article 34 of the Rules, a committee to count the letter ballots which had been cast for officers, and to report at the session on Wednesday morning. Messrs. Wm. T. Bonner and Paul M. Chamberlain were made such a committee of tellers. He then called upon Prof. Sidney A. Reeve for the presentation of his paper on "A Rational Solution of the Problem of Weights and Measures." Messrs. Suplee, Lewis, Halsey, McGill, J. D. Riggs and G. W. Colles, contributed discussion.

The Secretary made announcement concerning the details of the meeting; the presiding officer spoke of the social opportunity in the collation room below the meeting hall, and the session then adjourned until the following morning.

Second Session. Wednesday Morning, December 3rd.

The meeting called to order by Vice-President Arthur M. Waitt, at 10.30, in the banquet hall of the Sturtevant House. The registration of the members in attendance was slightly modified at this meeting, by the use of separate sheets with carbon impression, so that the printed list from the register might be circulated more promptly by saving the time necessary hitherto to copy them from the pages of the official registration book. The same care was taken as at a previous meeting, to keep the names of members and guests distinct from each other. The large number registered preclude a full reproduction of its pages, but there were 474 members and 225 guests included in the total of 702.

The first business of this session was the presentation of the Report of the Council as required by the Rules. This report had been prepared some weeks in advance of the meeting, and had been printed and distributed to the members. It was therefore presented at this meeting, by title, the Secretary adding a concluding paragraph to the printed copy, to include transactions of the Council since the report was printed, which will be found in their proper place at the end of the regular report as distributed to the membership.

The Chair put the motion on the Report of the Council and stated that the Council, through the Secretary, were prepared to answer the questions which any member might like to ask on the subjects covered in the report. No such questions being asked the report was on motion, received, and ordered on file. The report is as follows:

ANNUAL REPORT OF THE COUNCIL.

The Council, under the provision of the Rules, presents to the Society, convened for its twenty-third annual meeting, the report of business which has been considered during the year, and of action which has been taken.

It has been an occasion of keen regret that the Society has been compelled to forego the services of its President, Mr. Edwin Reynolds, during the latter part of the year, by reason of his continued ill-health. The President was present at the first three meetings of the Council, but was unable to attend the convention in Boston and to preside at the meetings of the Council and Society. He also advised the Council that he would be unable to attend meetings in the fall and winter during his term of office, and asked that provision be made for his place to be supplied by one of the Vice-Presidents. Mr. James M. Dodge has supplied his place both at the spring meeting and at the meetings of the Council previous to the annual meeting.

The routine business of the Council in any year is made up in part of considering requests for the gratuitous distribution of its *Transactions* to libraries and the consideration of candidates making application for membership. During the current Society year the Council has acted favorably upon applications for membership, divided among the grades as follows:

	Spring Meeting.	Annual Meeting.	Total.
Members	58	58	116
Associates	17	10	27
Juniors	49	34	83
Total	124	102	226

By reason of the agitation in the fall of 1901 for an increase in the sum to be paid as computation of dues for life, in the form of Life Memberships, there were eighteen such memberships created last year, bringing an aggregate of $3,600 to the Society from this source.

The Council has also had the pleasure of acknowledging the receipt of gifts from members during the year, and would make particular reference to the receipt of a model of the rifle made by American tools in Kimberley, South Africa, during the early part of the Boer War, and which was designated as "The Long Cecil." The Council has transmitted the usual vote of thanks to those who have favored the Society in this way.

In the summer of 1901 a proposition appeared in one of the daily papers of New York City, urging on those interested that the bust of the late Alexander L. Holley, now standing on a pedestal in the westerly part of Washington Park, had ceased to occupy the position of honor to which Mr. Holley's memory and achievements were entitled. It will be remembered that Mr. Holley was a Vice-President of the Society in its early formation, and was honored by being created "Founder of the Society" at the time of his death, in 1882. The bust had been erected by joint action of the engineering societies and personal friends of Mr. Holley, who had subscribed for a fund for this purpose, and it was transferred to the city of New York, with appropriate ceremonies, in November, 1890. While the location in the Washington Park was at that time recognized as not the best, it was the only one available, but the changes in the city during the period have made the location less and less suitable as the years went on.

The Council took the question up by appointing a committee of its members, who had conferences with the other organizations interested in the original gift of the bust, and, after obtaining the concurrence of all concerned, the proposition to give the bust a more suitable and distinguished location was presented to the Commissioner of Parks. By reason of difficulties with respect to the legal aspects of a transfer of property which has been deeded to the city, the Committee up to the present time has only a report of progress to make.

The Council has been requested to approve a proposition to appoint two members of the Society to act as a joint committee with delegates from the American Institute of Architects to plan and arrange for tests upon Steel I-Beams of Large Size. The request was made by the State Architect, and after conference with the American Institute of Architects, the Council directed that

Messrs. H. de B. Parsons and Palmer C. Ricketts should be the representatives of this Society upon such a joint committee.

The Council has tendered the use of its auditorium and other public rooms to the New England Cotton Manufacturers' Association on the occasion of their Seventy-third Meeting, in New York City, September 30th to October 2d.

The Council has also, on the recommendation of its Executive Committee, authorized the issue of the following circular, pursuant to the action which it took in May, 1896, on the occasion of the previous agitation concerning a legislation which should make the use of the Metric System compulsory. The circular was as follows:

AGAINST COMPULSORY USE OF THE METRIC SYSTEM.

THE EXECUTIVE COMMITTEE OF THE COUNCIL HAS DIRECTED THAT THE FOLLOWING CIRCULAR AND REPORT SHOULD BE ISSUED TO THE MEMBERSHIP.

PHILADELPHIA, U. S. A., *February* 19, 1902.

To the Council of the American Society of Mechanical Engineers, New York City:

Gentlemen: The Committee of your Society to whom has been referred the consideration of the metric system in comparison with the system in use in the United States, at a meeting held in Philadelphia to-day at which were present the subscribers in person or by letter, begs to report as follows:

An attempt is being made through the Committee on Coinage, Weights, and Measures of the Fifty-seventh Congress in reference to H. R. Bill No. 2,054 supplemented by H. R. Bill No. 123, compelling the adoption of the (French) metric system of weights and measures in all departments of the Government in all its workshops and in all matters connected with construction or commercial operations other than those relating to public lands and surveying. In this bill on lines 9, 10, and 11 it will be seen that after fixing a date for its compulsory use, it states that the metric (French) system of weights and measures shall be *the* legal standard of weights and measures recognized in the United States. The word "the" on the tenth line must be considered as meaning the *only legal* standard, for the reason that the French metric system of weights and measures is now and has been for many years legalized by Act of Congress, and is as free to be used and as legal in the use as are the pounds and tons or yard, feet and inches heretofore and at present commonly used in this country. If this bill is passed it will make what we are now using to such good advantage illegal. The attention of the members of this Society is therefore called to the proposed legislation, and it is earnestly urged by the Committee that all members should address their respective representatives in Congress protesting against the passage of H. R. Bills No. 2,054 and No. 123, expressing in the strongest terms their opposition to a measure involving changes that will inconvenience and hinder trade and manufacturing, and requiring an expenditure of time and money that cannot be expressed in figures sweeping away as it does the advantages accruing from the numerous estab-

lished standards now recognized and universally adopted throughout the country.

Respectfully submitted,

COLEMAN SELLERS,
COLEMAN SELLERS, JR.,
GEO. M. BOND,
J. E. SWEET,
CHARLES T. PORTER.

The Council also approved the recommendations of its Executive Committee that the *Employers' Bulletin* should be issued at intervals until further notice. Attention is directed to the Report of the Executive Committee with respect to the service which the issue of these bulletins has rendered.

The most important subject which the Council has had under consideration during the current year has been the outcome of its careful investigation into the financial questions affecting the Society at this time. The Council reported in circular form to the membership in May of the current year the results of its discussion of this question, and repeats for record in its *Transactions* the report of their deliberations at that time on matters of permanent policy.

The resolutions in this group are as follows:

1. *Resolved*, that the fiscal year of the Society run from October 1st in each year to the succeeding September 30th.

2. *Resolved*, that the Council approve the recommendation that the accounts of the Library Association be incorporated into the books of the Society, and that in the accounting the two organizations be treated as one, without in any way invading the right of control of the Library Association as to its work or its income, by its Trustees, and without invading in any way the rights of any persons who are subscribers to its support.

3. *Resolved*, that the Treasurer be authorized under the direction and with the approval of the Finance Committee to borrow such sums as may be required in the current year for the proper conduct of its financial affairs, and that the Treasurer have authority to sign the name of the Society to such notes as may be required under this procedure.

4. *Resolved*, that the action of the Finance Committee be approved and confirmed, whereby under the direction of the Executive Committee the Treasurer was directed to effect the necessary loans from the East River National Bank.

5. *Resolved*, that the Council approve the following appraisal values of the real estate, library, and stock of *Transactions*, and direct that these values be entered upon the books of the Society as of the date September 30, 1901:

Real estate	$85,000
Library	10,000
Transactions	15,021
Furniture	1,300

6. *Resolved*, that the recommendations of the Finance Committee be approved, creating a special account, to be known as "Library Account," to which on September 30th of each year shall be posted an amount equal to 1 per cent. of the gross receipts from membership dues accruing during the fiscal year then ending.

7. *Resolved*, that the whole of the receipts from initiation fees and life memberships shall be credited as received to a "Reserve Fund," that at the close of each fiscal year 10 per cent. of the total amount to the credit of this reserve fund shall be transferred to "Annual Income Account," and as such shall be applied to current expenses; that the balance of said fund shall be held or invested as a "sinking fund," to be applied to the liquidation of the indebtedness of the Society and of the Library Asociatien, in such amounts and at such times as the Council may direct.

8. *Resolved*, that the Council approve the action of the Executive Committee whereby economy of management and administration have been secured with respect to the curtailing for the present of the general distribution to all members of advance papers before the meeting; the discontinuance of gratuitous distribution of revised papers with discussion after the meetings; the diminished use of the return postal cards, and the issue of only two lists of members during the year, one of which shall be the alphabetical list, without geographical distribution, and the other the smaller "vest-pocket size" containing the list of members arranged geographically.

9. *Resolved*, that a committee be appointed by the President to consider a general revision of the rules of the Society as proposed by the Finance Committee, in the following resolution of that body:

"*Resolved*, that the Finance Committee recommend that a committee be appointed to make a general revision of the rules of the Society, especially with respect to the status and duties of the Finance Committee, and further, to consider such amendments or changes in the rules as may be or have been proposed by members of the Society

"The Finance Committee further recommends that the special committee to be appointed under this resolution be instructed to formulate a constitution which shall be adopted or amended only by vote of the entire membership; by-laws to be adopted or amended by the Council; and rules to be made or altered by standing committees of the Society, with the approval of the Council."

The Council appointed its Executive Committee and the Finance Committee of the Society a joint committee to take under consideration the preparation of a system of accounting which should reduce the labor in the office of the Society, on the one hand, and, on the other, enable the Council to be more easily informed at any time of the exact amount of income and expenditure to be expected in any fiscal year of the Society.

Under this authority the Executive Committee secured the services of the firm of Messrs. Sargent, Page and Taylor, public accountants, who investigated the accounts of the Society and proposed improved methods in detail. The accountants found the books to be in proper order and correct, but made suggestions as to the form in which the annual report should be presented, which have been followed in the report from the Finance Committee, which is appended to this report. The Council has directed that until further notice each standing committee at the end of the year shall report to the Council the work which has been done under its direction during the preceding year. Such reports are also appended to the reports of the Council.

In comment on these reports of its Library and House Committee, Publication Committee, and Executive Committee, the Council would ask attention of the members to the facts which are presented with great fulness therein. It may not be generally appreciated how wide the scope must naturally be of the work intrusted to committees in an organization the size of the Mechanical Engineers, and it is believed that a careful reading of these reports will give much valuable information.

With respect to the report of the Finance Committee, the Council would direct attention to the fact that it contains statements of the cash receipts and disbursements. It presents, second, statements of the assets and liabilities of the combined organizations of the American Society of Mechanical Engineers and of the Library Association; it contains, also, a statement of income and expenditure of the Society during the current year. From these financial statements the Council has drawn off the following facts and conclusions, for which it bespeaks the careful consideration of the members:

Items educed from the accounts of the last year showing the cost per member:

(1) Total number on catalogue		2,424
Deduct life members	106	
Deaths and resignations	10	
Lapsed memberships	70	
Members who have not paid current year at September 30, 1902	179—	365
Paying membership		2,059
(2) Total receipts exclusive of initiation fees ($4,485), life memberships ($3,600), and fellowship fund ($532)		$34,797 49
Received per paying member (computed)		16 90
Received per member for dues only (computed)		13 58
(3) Total expenses of year October 1, 1901, to September 30, 1902, except operating house ($824.43), mortgage interest ($1,402.50), and repairs and renewals (470.64)		34,756 53
(4) Total expended for publications, October 1, 1901, to September 30, 1902		16,523 16

(5) Total expended for salaries in Society's office, same period...		$9,440 00
(6) Total expended for all other expenditures, except house.....		8,793 37
(7) Total expended for house, including interest on mortgage and repairs and renewals..............................		2,697 57

Expenditure per paying member, October 1, 1901, *to September* 30, 1902 :

(8) For all purposes including house..........................		$18 19
(9) For house operation including interest and repairs..........		1 31
(10) For all purposes exclusive of house........................		16 88
(11) For publications, printer's work, engraving, binding, and distribution..............................	$8 02	
(12) For salaries in Society's office......................	4 58	
(13) For all other purposes except house..................	4 28	
	$16 88	
(14) For house operation exclusive of mortgage interest and repairs and renewals................................		40
(15) For house operation exclusive of mortgage interest, but including repairs..................................		62
(16) For operating the library..................................		53
(17) For expenditure for postage, circulars, catalogues, and printing in Society office................................		2 18
(18) For meetings and all other expenditures not otherwise allotted above..		1 42

In further comment on these computations, and the tabular statements of the Finance Committee, the Council would ask the members to consider the following points:

1. The present Life Membership fee is $200; the income from this sum invested in any safe way will be less than the annual expense per member, which is stated above to be over $17. It is obvious, therefore, that the Life Memberships are a drain on the resources of the Society at the rate at which the present membership are receiving return for their dues. It is obvious that the Life Membership fee should be materially increased.

2. The present large proportion of Junior members as compared to the entire membership causes a financial drain, because the sum actually received from Juniors ($10) is so much less than the corresponding expenses incurred on their behalf by the Society. There are 566 juniors bringing in an income of $5,660, as against $9,454 expense incurred on their account.

3. The sum ($3,600) received this year in payment for Life Memberships is used for reducing liabilities, and has not been laid aside as an investment in income-bearing funds.

4. The entire receipts from initiation fees of new members are used as income for current needs. This is not believed to be a sound permanent financial policy. The receipts from this source will not continue indefinitely, and are liable to fall off with any year of industrial depression. The income from regular sources should be enough to carry on the Society, leaving the whole or a large part of the initiation fees as a permanent fund. (See Resolution 7, p. 9.) If 90 per cent. of the initiation fees had been withdrawn as an investment fund ($4,036) as directed by the Council, there would have been a deficiency for the year 1901-02, instead of an excess of income as reported on Sheet B.

5. The margin of difference between the total of receipts and the total of expenditures is not large enough to permit of the Society's incurring any additional obligations. There have been no monthly reunions for this reason this year; projects for extending the usefulness of the library to members have been blocked, and there is no reserve fund of consequence should extra expenses be made necessary in any year.

6. The average annual amount reported by the House Committee for repairs, maintenance, furniture, and fixtures has been an average of $1,200 per annum; the sum expended this year for this purpose is only $824. The presumption, therefore, would be that in some subsequent year an increased expenditure will have to be made to meet the accumulated deterioration.

7. The account makes no provision for the setting aside of any sum to diminish the mortgage of $33,000 still remaining on the house. A part of the debt which has accumulated during the last two years is due to the effort to set aside a sum for the reduction of the mortgage indebtedness greater than the income of the Society during those years would altogether justify.*

* It may be serviceable to record the sources from which the equity of $52,000 which appears in sheet C has been secured. It results from the following transactions:

Cancellation Second Mortgage Bonds—

By Gifts of Bonds	$2,000
" Surrender of Bonds for Life Membership	8,200
" Purchase with cash from regular sources in ten years	16,300
" Purchase with special Library Funds	5,500
Total	$32,000
By Increase in Valuation	20,000
	$52,000

8. The library of the Society, appraised at $10,000, is the only free public library on mechanical subjects in New York City. The Committee has recommended that the sum of $300 to be expended annually for additions to the library. The expenses for the current year have been mainly for maintenance, and a sum of money much less than this has been expended for growth.

The Council would call attention to the Appendices, which reproduce in condensed form a part of the discussion in its circular of May 10, 1902. The figures have been revised to agree with the results of the accounting during the year.

The Council would report for record the following deaths in the membership during the year: John M. Bogle, March 7, 1901; J. B. Henney, November 2d; Frederick Stieltjes, December 27th; Walter V. Fitch, January 2, 1902; Charles P. Deane, January 9th; Hezekiah Conant, January 22d; Francis A. Pratt, February 10th; R. G. Ewer, February 21st; Jerome Wheelock, February 26th; Charles H. Nicoll, February 27th; Bryan Donkin, March 4th; W. L. Hoffecker, March 18th; Thomas Forsaith, April 5th; Henry Morton, May 9th; W. V. Lidgerwood, June 2d; Robert B. Reading, June 16th; J. B. Johnson, June 23d; John H. Hall, June 25th; Joseph Cavanagh, July 1st; Hiram F. Lord, September 15th; John S. Klein, July 16th; George W. Weeks, October 7th; William D. Caldwell, October 10th.

The Council has directed that under the provisions of Article 19 of the Rules the following action should be taken with respect to delinquents:

1. That any member, associate, or junior, who owes for the current year only, shall be carried forward on the books and his name retained on the Annual Catalogue. His debt to the Society shall be considered as an available asset.

2. That on September 30th of the succeeding year, if more than one year's dues remain unpaid, his name shall be transferred to the "Suspended List," taken from the roll of the published catalogue, and his account transferred to the "Bad Debts Account." From the Suspended List he may be restored to membership and the published roll, by action of the Council, without reëlection or general vote of the Society.

3. Names which have remained one year upon the Suspended List shall be dropped at the end of that time without further action of the Council, and such persons may only return upon applying for membership as new candidates, the Council to decide in each case whether the candidate shall be compelled to pay an initiation fee upon this second election.

Under this ruling the accountant was directed to carry forward

179 members on the roll who were in arrears for one year's dues only, but to withdraw seventy names of those who had allowed their membership to lapse under the foregoing ruling. The revised enrolment of the Society in its various grades, under this action, at the end of the fiscal year is as follows, not including the members to be voted on for admission at the annual meeting:

Honorary members	18
Life members	106
Members	1,606
Associates	174
Juniors	551
Total	2,349

Respectfully submitted,

THE COUNCIL.

APPENDIX I.

THE COST OF OPERATING THE SOCIETY.

It will be apparent from a study of the accountant's report that the principal elements of expenditure fall under the following heads in the order of their magnitude:

1. The *Transactions* or publications.
2. Salaries of officers and staff.
3. The headquarters or house of the Society.
4. Sundry printing, circulars, postage, meeting expenses, and miscellaneous.

The Council has considered each of these headings and presents the following conclusions:

1. The *Transactions* or Publications of the Society.

Economy may be effected here in two ways: The number of accepted papers may be reduced, and the size of the annual volume which goes to each member; or the mechanical standard in printing and illustration may be lowered, and the price cut, without impairing the professional value of the volume; or both of these courses may be taken at once. It is the emphatic opinion of the Council that the first alternative should be taken only in the last resort. The volume of the papers is to many members of necessity a very valuable return from membership; the quality of the papers gives the Society its repute and standing at home and abroad; these papers are the reason and cause for succesful and valuable conventions of members; they are the principal appeal for accessions of new members and the continued growth of the Society. So far from curtailing here, the Society should expand in the direction of more papers, of wider interest, of superior quality and usefulness, even if it must expend something more to attain these results.

On the other hand, the effect of lowering the mechanical standard of printing and illustrating the papers is not so far-reaching. A cheaper grade of compositors can be employed; a diminished number and size of illustrations can be admitted; folding plates may be eliminated or reduced; the elegant wax process for cuts can be replaced by cheaper reproduction processes; tabular matter can be cut out or diminished; coated paper for half-tones can be discontinued. With respect to the distribution of papers, the edition of papers issued in advance of meetings has been cut down in size, and such papers sent only on order, and not to every member before a meeting, as hitherto. Members have been charged for each copy of every revised paper they order after it has been read and discussed.

The Council hope, however, that as soon as possible the Society will order a return to the more liberal and satisfactory standard which has prevailed hitherto. As it is, however, the report of the Publication Committee makes it apparent that this Society is spending less on its publications in an average year than its kindred societies of similar size and aim.

2. The Salaries of Officers of the Society and the Office Staff.

The Secretary of the Society is its only salaried officer. The Treasurer receives no compensation, but the accountant in the office is the Treasurer's assistant and clerk. Any further clerical assistance which the Treasurer may employ, he pays for himself out of his own pocket. The staff in the Society's office consists of one accountant, acting mainly as such and as assistant to the Treasurer, one stenographer, one assistant librarian, and one mailing clerk who acts also as order clerk. The volume and extent of the business in the office precludes any consolidation of these duties among a less number; or, in other words, the work could not be done at all with a reduction of force to less than one in each department. The work of the Secretary of the Society as editor of its *Transactions*, as chief librarian, and executive officer for the Council, is discharged by a secretary and an assistant. This organization prevails in all the large engineering societies doing work upon the scale followed by this Society. The Mechanical Engineers are unique in this, however, that for the service of these two men it pays a sum no larger than is paid to one man in the other societies. This arrangement seems so favorable that the Council have no desire to disturb it, particularly in view of the satisfactory quality and extent of the service rendered. The report of the Executive Committee makes it apparent, furthermore, that this Society is paying less for salaries and staff than the other engineering societies of the same kind. The Council has not thought it wise to make any readjustments in this particular. The amounts of the salaries in detail will be found in the reports of the committees, and those of the house staff are considered in the next paragraph.

3. The House serving as Office and Headquarters for the Society.

The accountant reports that the net cost of operating the house, No. 12 West Thirty-first Street, New York, last year, including wages and mortgage interest was $2,697.57. A careful computation of the minimum floor space upon which the Society's work could be conducted in its relations as a national organization would be 1,200 square feet, in order to give desk room for Secretary and assistant, for accountant and stenographer, with safe and records, and for mailing clerk, with his supplies and files. The prevailing rental in office buildings in this city averages from $2 to $3 per square foot. If this Society rented its quarters it would have to pay, therefore, at the rate of about $3,000 per annum for its office functions only, and would have to rent a hall for its meetings, and forego its library and its public functions altogether. To give up the house would be also to abandon the advantages attaching to non-resident members as to the use of rooms, and to forego all the sentiment and prestige which belong to the ownership of a house. It appears to the Council so greatly to its financial advantage to keep on in the present way, to say nothing of the imponderable advantages, that there can be but one conclusion. The house staff requires one house matron and superintendent (whose duties are consolidated with those of assistant librarian), a janitor who is also the fireman, and a maid. This is a minimum for effective service, and could not be reduced. Their wage is at the prevailing rate for such work, as detailed in the report of the House Committee. If an interest of 4 per cent. on the equity of $52,000 be added to the operating and interest cost, the total becomes only $4,306.93, which is not a large price for what the Society receives in return.

4. Circular Printing, Meeting Expenses, Postage, Miscellaneous.

It is apparent that in this heading alone the considerable cut must be made, if the efficiency of the Society is not to be seriously impaired. Accordingly, it is here that the Executive Committee has cut its estimates most severely. It has reduced the number and quality of its catalogues; it has diminished the number of circulars issued; it has consolidated the transmittal into a less number of inclosures; it has increased the proportion of expense of the New York meetings to be borne by local subscription; it has cut the use of return postal cards with prepayments; it has reduced the scope of circularized material.

The Council would call attention to the fact that salaries and house charges are the only elements of expenditure which are independent of the size of the Society, and are thus truly fixed charges. The costs of publications, of clerk hire, of circulars, of postage, and of meetings grow with the growth of the Society, while the only independent items are one-third of the total expense. It is this fact which explains in part why the cost of the Society should increase with its growth in members, or why the cost per member does not fall so rapidly as it would where increased output was not accompanied with increased operating expense. (See Table in Report of Finance Committee.)

APPENDIX II.

REPORT OF THE LIBRARY AND HOUSE COMMITTEE.

To the Council of the American Society of Mechanical Engineers:

Gentlemen: The Library and House Committee presents the following report of its action during the current year:

I. The library has been open every day between the hours of 10 a.m. and 10 p.m.—excluding Sundays and legal holidays—except evenings in the month of August. The additions to the library in the form of exchanges, which have been received as the equivalent of an annual volume of the Society's *Transactions*, have amounted to $303.

The Committee has expended for the purchase of books and for the binding of periodicals and pamphlet *Transactions*, the sum of $471.50. There has also been received, from dealers purchasing duplicate volumes, $40, and there remains a credit to the Society with the house of D. Van Nostrand & Co., on this basis, of $287.80. Since December, 1901, visitors to the library have numbered 1,500, averaging six persons a day, excluding July and August, when there are generally few persons there.

For the conduct of the library work the Committee has had this year the services, for a part of his time, of Mr. Arthur L. Rice, assistant to the Secretary, and the continuous services of Miss Thornton as librarian and cataloguer. The manuscript of the card catalogue has been completed, so far as the book titles are concerned, but by reason of the expense involved the catalogue has not been printed for distribution. The number of volumes in the library at the date of this report is as follows:

Books	8,267
Pamphlets	2,200

The appraised value of the library at the beginning of the year 1902 was placed at $10,000, this being the mean of the two appraisals which are appended to this report.

II. During the fiscal year the Finance Committee appropriated for the needs of the house the sum of $5,191.40, distributed as follows:

For operating expenses	$3,318 26
For interest on mortgage	1,402 50
For repairs and additions	470 64
Total	$5,191 40

The receipts on account of room and hall rentals for the year have aggregated $2,493.83. This makes net cost of operating house, $824.43, and the total cost, exclusive of interest on equity, $3,227.57. The Committee directed the renewal of paper and paint in certain of the rooms in the upper part of the house, and repairs to the side walls in the reception-room, at a cost of $172, in addition to other ordinary repairs during the year, amounting to $169.23, of which $67.16 was caused by repairs made necessary by a leak in the roof, and $25.73 by repairs to a water connection due to a break in the pipe connections from the city main in the street, leaving $76.36, which has been expended for other repairs, of which $49.70 was for painting and papering in the fall of 1901. The expenditures in detail have been as follows:

Interest on mortgage	$1,402 50
Gas and electric light	547 59
Fuel	247 25
Janitor's supplies	143 97
Laundry	437 97
Additions, new furniture, etc.	44 50
Insurance	45 13
Repairs and renewals, house	340 00
Repairs and renewals, furniture	130 64
Wages	1,740 00
Incidentals	156 35
Total, exclusive of depreciations on furniture and fixtures	$5,235 90

The Committee directed the purchase of two tons of coal in April, 1902, at $5.75 per ton, and of 45 tons in May, for the winter's supply, at $5.25 per ton, in all $236.25.

The House Committee employs, for the conduct of the house and library administration, a janitor and his wife (at $60 per month), and has the services, for part of the time each day, of a boy (at $45 per month), part of whose duties are connected with the work of the Society's office.

The auditorium has been used during the year for the meetings of the Institute of Electrical Engineers, of the Society of Naval Architects and Marine Engineers, of the American Society of Heating and Ventilating Engineers, and for certain meetings of the New York Railroad Club, and for occasional meetings of scientific societies (such as the Ethnographic Society), the receipts from this source amounting to $415. The receipts from the use of the sleeping rooms, on the upper floors of the house, during the year have amounted to $2.078.83.

The Committee was called on in the spring to report to the Council the amount which should be set aside each year for library purposes. The Committee reported that in their opinion the sum to be set aside each year for the purpose contemplated in the creation of the account designated as "Library Account" should be about $300. In view of the fact that the sum due at present from the membership in the form of dues is in the neighborhood of $30,000 per annum, the Committee recommended to the Council that it should fix the percentage of such dues to be credited to the library fund for the present year at 1 per cent. Two past members of the House Committee were requested by the Finance Committee to investigate and report upon the expenditures made in the past for repair and maintenance of the Society's property. The report of such past members of the House Committee, with their recommendations, is appended to the present report.

Respectfully submitted,

LIBRARY AND HOUSE COMMITTEE.

APPENDIX III.

NEW YORK, February 20, 1902.
977 Lexington Avenue.

Prof. F. R. Hutton, Secretary, American Society of Mechanical Engineers, 12 West 31st Street, New York City:

Dear Sir: Acting on your request contained in your letter of the 10th inst., I have the honor to report that I have made an examination of the library of the American Society of Mechanical Engineers, finding, as a result, about 7,600 volumes and 2,000 pamphlets on its shelves, to which I fix a value of $14,000.

In general, it proved to be a well-selected collection on mechanical engineering, with the more important recent works on electrical engineering. The stress laid upon complete files of the technical and trade periodicals is wise and will be approved by workers in current technical research.

Very respectfully,

H. M. LYDENBERG.

NEW YORK, March 3, 1902.

Prof. F. R. Hutton, Secretary, American Society of Mechanical Engineers, New York City:

Dear Sir: Agreeably with your request, I have made a careful examination of the books in the library of your Society, and as a result of such examination, conclude that a fair valuation of same would be eight thousand dollars ($8,000).

I would remark that there are in the library many incomplete sets of serial publications, the missing portions of which can, in many instances, be obtained at nominal cost, and if obtained would add materially to the value of the library.

I would be glad to aid the library in the matter if desired, and inclose herewith bill for services rendered, and am,

Yours very truly,

C. E. SPEIRS.

APPENDIX IV.

NEW YORK, April 12, 1902.

To the Finance Committee of the American Society of Mechanical Engineers:

The undersigned Committee, appointed to report upon the past expenditures of the Society for repair and maintenance of the Society's property, and also to recommend a suitable amount to be set apart annually for such expenditure in the future, respectfully reports as follows:

1st. From the statement of the expenditures of the Society on this account for the past ten years, furnished by the Secretary, it will be seen that the total amount expended during that period was $17,522. This includes, as per the following statement:

	Furniture and Fixtures.	Equipment.	Repairs
1892	$261 99	$246 72	$189 33
1893	945 16	451 50	119 95
1894	642 43	363 50	15 29
1895	287 21	336 78	328 50
1896	848 88	245 20	338 73
1897	451 62	423 41	325 46
1898	656 07	12 75	672 21
1899	592 27	62 25	1,138 02
1900	614 25	......	537 98
1901	317 66	......	1,610 96
Totals.........	$5,617 54	$2,142 11	$5,276 43

Furniture and fixtures....................................	$5,617 54
Equipment	2,142 11
Repairs	5,276 43
Total	$13,036 08
Heating and ventilating.....................................	4,486 00
Total	$17,522 08

Certain large items, namely about $4,500, for the heating and ventilating apparatus, about $1,000 for electric wiring, and about $500 for the construction of store closets. are not at all likely to be again required.

2d. Taking into account the above figure, it appears that the average expenditure during a period of ten years has been $1,750 per year. Omitting the above-mentioned items, we consider that an appropriation of $1,200 per year will be suitable for the maintenance and repairs of the property.

Respectfully submitted,

JESSE M. SMITH,
H. H. SUPLEE.

APPENDIX V.

REPORT OF THE PUBLICATION COMMITTEE.

To the Council of the American Society of Mechanical Engineers :

Gentlemen: The Publication Committee of the Society has been giving consideration for several months to the question of securing greater economy in the mechanical work of printing the volume of *Transactions*. The question naturally involves two issues.

The first was a reduction in the price paid to the present printer, by an alteration in the form of the contract, and

Secondly, the procuring of bids from other houses capable of handling the publishing of the Society's volumes.

The Committee has taken steps in both of these directions. As the result of the first procedure, the form of contract with the present house has been amended, so as to reduce the cost of a typical volume of the *Transactions* by a sum, which, while it will, of course, vary with the size of the volume, is likely to be for an average volume (such as volume xxi.) a reduction of $2,300 in the cost of the yearly volume.

The second question was whether, by securing a contract with another house doing hand composition, it would be possible to procure more advantageous terms, or whether, by substituting the type-setting machine for hand-work, with the present contractor or with some other, it would be possible to effect an economy, while keeping up the standard of the volume in the matter of mechanical excellence.

It should be recalled that the requirements of the Society upon its printing house are exacting, by reason of the fact that the Society practically issues one-half of its volume at high speed within a few weeks in advance of a meeting, and then holds the type of that half volume standing, while the discussions which are held at the meeting are inserted in their proper places at the close of the paper to which they attach. This means that the type for one-half the volume must be completely set up within a few weeks, and kept locked up at the service of the Society for a period which averages four months, twice a year, or eight months of the entire year. The Society's work requires also the use of mathematical symbols, subscript letters, and the difficult work of setting up equations and tabular matter, which is not possible by the type-setting machine method.

It was found that several of the largest printing houses in the vicinity did not care to consider the undertaking of our work, by reason of its conditions with respect to rapid composition and locking up type, and for others the demand for type was beyond their capacity. The Secretary's office furnished the various competitors with a standard specification and sample volume as to standard of quality, using volume xxi. for this purpose, as being a volume of average type. The competing firms were six in number, and the result of their bids reduced to a common standard for volume xxi. by careful computation give the figures shown in a confidential appendix of this report.

It was the opinion of the Commitee—

1. That the difference in price for hand-work by the various firms, as compared with the present contract with the house of J. J. Little & Co., did not warrant the Committee in recommending a change to any of these houses; particularly since J. J. Little & Co. agreed to set such papers as admitted it by machine, and give the Society the benefit of the machine rate where it could be applied.

2. The question then was as to the acceptance of the proposition of one of the approved bidders to do the work entirely or largely by the type-setting machine at its reduced rate. It was the opinion of the Committee that by reason of the proportion of work which would have to be set up by hand in any case, the expensive character of corrections, and the difficulty connected with them (which are very frequent in scientific and technical articles prepared under the strain to which many of our members are necessarily put when they undertake such work), and the uncertain character of the actual saving for these reasons, as compared with the computed saving in advance of experience, that there were not sufficient reasons to induce the Committee to recommend a change, in view of the inconvenience, delays, uncertainties, and other drawbacks, which would be the unavoidable consequence of making a change of this sort, and the possibility of using machine processes with the present contractor, where this would be of advantage to the Society.

The Committee therefore recommends that for the present there should be no change made in the selection of the Society's printer, but that the Council approve the form of contract with the house of J. J. Little & Co., on the basis of which the economy will be made which is referred to in paragraph 2 of this report.

The Committee would also report upon the conduct of the current work of the year under its charge.

The appropriation for the work of the Committee at the beginning of the year was distributed as follows, and under the following headings. The amounts which have been expended for the volume of the current year under each head, as taken from the Society's accounts, show the total for the year $7,920. The round figures are:

Advance papers	$1,250
Revised	679
Stenographer's fees	255
Engraving	324
Composition and electrotyping	4,977
Binding	108
Boxing plates	13
Postage and expressage	194
Storage, including insurance	120
	$7,920

The Committee has also expended on account of work coming over to it from its previous year the sum of $8,600, making the total cash payments for the year under its direction $16,523.16.

This amount carried forward is made up of:

Pamphlet papers	$924
Engraving	279
Composition and electrotyping	4,241
Binding	1,958
Boxing plates	10
Postage	1,068
Storage	120
	$8,600

In comment on these figures the Committee would direct attention to the fact that the reason why the grand total exceeds the statements which have been made in previous years, is the allotting of certain expenses—such as the stenographer's fees, the storage, the expenses of shipment—to the appropriation for the Committee's work instead of charging these either separately or as part of the office expenses of the Society, as prevailed in previous years. Furthermore, a much greater effort has been made this year to bring expenditure for publications apportioning itself to the current year, into the items which the Committee reports in that year. In previous years less effort was made to secure this result, so that items chargeable to the volume of a given year were completed and paid for in the next succeeding year, as indicated above. While this procedure evened itself up in the long run, the definite cost of any single volume was not so easy to reach, as under the present system.

The Committee did not consider that it had been instructed by the Society or the Council to curtail its operations with respect to accepting desirable papers, but only to pursue a policy of retrenchment in the matter of expensive tabular matter, elaborate illustrations, and similar mechanical detail. The volume of the current year contains 900 pages, but the Committee has had to pay for the work of setting up and issuing the report of the Committee on Conducting Engine Trials, which is not made a part of the current volume, and will not be incorporated into a volume until the Society has taken action upon the work of the Committee and releases it. For this reason, and because of the infusion, by the new system of accounting, into the expenses of the *Transactions* of certain items which in previous years have been charged up to "general expense" in the office routine, the Committee was compelled to exceed its own estimate of the sum which should properly belong to the work of the Committee.

By reason of the different methods of accounting in the various societies, the Committee is not confident that in the investigation which it conducted as to the relative cost of the publications in this Society and in two of its kindred societies, it was able to present a fair comparison. Subject to this uncertainty the Committee would present for record the result of computations covering the last five years, in the following table taken from published reports:

RELATIVE COST OF PUBLICATIONS.

Year	Civil Engineers.	Mining Engineers.	Mechanical Engineers.
1896	$8,763 38	$9,212 00	....
1897	8,450 00	10,592 00	....
1898	11,000 00	11,447 00	$10,973 00
1899	10,723 00	9,475 00	9,643 00
1900	14,843 00	11,582 00	12,798 00
1901	....	13,554 00	12,740 00

Respectfully submitted,

PUBLICATION COMMITTEE.

APPENDIX VI.

REPORT OF THE EXECUTIVE COMMITTEE.

The Executive Committee of the Council has been intrusted by that body with special oversight with respect to the expenditures in the Secretary's office, which do not attach themselves directly to the work of any of the stated committees. The items which fall under the headings of such expenditure, in this group, and the amounts attaching to each are as follows:

Certificates and introduction cards.................	$172 25
Badges, expenses of distribution..................	21 33
Circulars	1,607 20
Meetings	1,049 62
Catalogues..	1,250 98
Office accounts, exclusive of salaries...............	1,444 92

The title "certificates and introduction cards" refers to the expenditure connected with the printing, engrossing, and distribution of the diplomas of membership, and the introduction cards which are given by the Society to each member when his initiation fees are paid. It will be apparent, therefore, that this item will vary each year with the number of members joining the Society, since the expense connected with each diploma and card is a definite sum for each. Similarly the expenditure for badges in the Secretary's office is the expenditure connected with distribution only, since the Society orders these badges from a jeweller, and they are billed to the members at the jeweller's price.

Under the head of "Circulars" the Committee has grouped the expenditure of each year into three headings. These headings are called "admission circulars" ($429.70), "circulars in connection with the meetings" ($705.55), and "general circulars" ($471.95). The expenditure covers the printing and the postage or expenses of distribution. The effort is made wherever possible to economize the postage by grouping these circulars into a single inclosure, even if by so doing the risk is made that the varied character of the contents of the package will fail to attract the attention of the members. The "admission circulars" cover application blanks, various confidential circulars of inquiry concerning candidates; the posting lists and the professional service sheets for the information of voters, and includes all expenses for postage in connection therewith. The "meeting circulars" cover programmes, the preliminary notice of meetings, the printed register of members in attendance, and all minor printing exclusive of the professional papers which belong to the two semi-annual conventions. Under the general head are grouped all circulars of an occasional or special sort. This year there have been very few such circulars issued outside of the six *Employers' Bulletins* except the pamphlet covering a financial report and statement with recommendations, which was sent to the members in advance of the Boston Meeting, costing over $100.

It will be of interest for the Committee to say that something over 250 persons have been brought into contact with the professional opportunities through the *Bulletins* and something over 150 employers in search of men have had their needs made known. The volume of correspondence incident to these 400 engagements is at least three times that of the number of persons or positions affected. In the opinion of the Committee this undertaking is decidedly worth while, and has been the means of bringing into touch with the Society, members who will add to its strength and importance. It will be apparent also that the expense connected with these headings will increase each year with the growth of the Society.

Under the heading "meetings" comes the expense in connection with the two semi-annual meetings which are not included under the expenses of printing and circulars. These cover those expenses in connection with the annual meeting, recurrent each year in New York City, which are not borne by individual subscription of the local membership. They cover also the expenses of the button badges, numbered tags, and the travelling expenses of the Society's officers in attendance on the conventions.

Under the expenses of "catalogues" is included the composition, press work, paper, and postage for the two issues of the catalogue of the Society. The first of these, which is the alphabetical list, is issued at the beginning of the calendar year, for desk use, and the second is issued during the summer with the members grouped geographically, in an edition small enough to be conveniently carried in the pocket. This summer edition contains the corrections of address which have been received during the preceding six months, and the additions to the roll of the Society by election since the previous issue.

The two catalogues, therefore, are not in agreement. So great is the number and volume of the changes of address during the six months' period between catalogues, that either issue is practically valuleless by reason of its inaccuracy by the time the next one appears. The large catalogue costs, with postage, a little less than $700, and the small catalogue a little over $500. Both of these catalogues were set up by the type-setting machine. They are freely issued to members and others, on demand, since it has been the opinion of the Committee that they are to be treated as a species of advertising literature, and have a distinct use in bringing additional members into the Society. For this reason the edition of each issue is made about 3,000. This, again, is an expense which will increase directly with the growth of the Society in numbers.

Under "Office Account" the Committee includes salaries in the office and the general expenditure for the conduct of its business. The salaries are as follows:

Secretary	$3,600
Assistant to Secretary	2,400
Accountant and assistant to Treasurer	2,000
Stenographer	720
Mailing clerk	720

It is the opinion of the Committee, after careful investigation of the volume of business which passes through the Society office during the year, that no reduction of office force could be practicable and have the business of the Society gotten out on time. The distribution of duties is such that each department requires the full time of the subordinate officer intrusted with it.

It may be of interest for the Committee to put on record the results of an investigation as to the amount expended for salaries in its kindred societies during the last five years, as derivable from their published reports. The table (including all officers of the Society and wages of employés) is as follows:

Year.	Civil Engineers.	Mining Engineers.	Mechanical Engineers.
1896	$11,645	$9,994	$7,384
1897	11,331	9,694	7,945
1898	12,826	11,144	8,045
1899	15,856	11,197	8,529
1900	16,282	11,984	8,933
1901	16,022	13,340	11,780

The expenditure for stationery in the Secretary's office, and the necessary printing for the correspondence, together, has amounted during the year to $300. The expenditure for postage, exclusive of such items as are specifically charged, has been $550, and is mainly for the office correspondence and for the business connected with the collection of dues. It will be apparent, again, that as the Society grows in size both of these items must increase in direct ratio.

Under the head of "Supplies" the office has purchased during the year an addressing machine, with a view to reducing the expenditure of time and money in connection with the very considerable mail issues which go out each year. It may be of interest for the Committee to say that in any one year there is a minimum of seven full sets of addresses prepared, covering the entire membership, and that in addition the ordinary volume of a year's business covers a minimum of transmittals through the Secretary's office of 43,000 units. In ordinary years this is more likely to exceed 50,000.

Respectfully submitted,

EXECUTIVE COMMITTEE.

APPENDIX VII.

NEW YORK, March 19, 1902.

Prof. F. R. Hutton, Secretary, 12 West 31st Street, New York City:

Dear Sir: Inclosed we send you our report as an Appraisement Committee upon the property at 12 West Thiry-first Street, which we request you to present at the next meeting of the joint Executive and Finance Committees, together with the accompanying estimates which have been made at our request by persons competent to make appraisements.

Very truly yours,

JESSE M. SMITH,
H. H. SUPLEE.

REPORT.

The undersigned were appointed by the Executive and Finance Committees to act as a special committee to report on the value of the real estate of the Society and the property contained in the house No. 12 West Thirty-first Street. They would present their report as follows:

I.

The property at No. 12 West Thirty-first Street falls naturally into four groups:

1. The house and lot.
2. The library.
3. The stock of *Transactions* of the Society.
4. The office and household furniture.

It was the intention of the Committee to have more than one estimate or appraisal made in each subdivision, and, if possible, to obtain three. This has not been possible in all cases. The Committee has obtained the services of the best available experts, and would base its recommendations upon the reports of these experts, which are appended to the report of the Committee.

II.

With respect to the real estate, the Committee would say that Messrs H. H. Cammann and Charles S. Schuyler have made independent estimates, and have valued the Society's holdings at $80,000. A third estimate at $90,000 has been furnished by Mr. S. W. Baldwin, as the result of a conference with four real estate men of experience in this neighborhood. A fourth estimate of $90,000, is based upon a sale at No. 14 East Thirty-first Street, which changed hands, at the rate of $3,000 per lineal foot of front face, and it is the opinion of experts that property west of the avenue always commands a higher rate than on the east side. The Society's lot at No. 12 West Thirty-first Street has 28½ feet front. It is the opinion of your Committee, therefore, that its value is in excess of $85,000, and would report that, in its opinion, its value should be placed at $85,000. The custom in this city and its neighborhod is to give no value to the house when land is bought and sold.

III.

The library of the Society, located on the second floor of the building, has been appraised by Mr. H. M. Lydenberg, who is an assistant to Dr. Billings, who is at the head of the New York Public Library. A second appraisal was made by Mr. C. E. Speirs, who is the active man in the firm of D. Van Nostrand & Co. The Committee was unable to secure the services of a third competent expert.

The value assigned by Mr. Lydenberg is............	$14,000
The value assigned by Mr. Speirs is.................	8,000

The Committee, therefore, recommend that the present value of the library be considered to be $10,000. This appraisal does not cover the permanent fixtures such as shelves, or furniture, but applies to books only.

IV.

With respect to the value of the stock of volumes of the Society's *Transactions*, the Committee finds that the average cost of reproduction in an edition of 250 copies, will make the cost of replacing a single volume, in paper binding, amount to $1.10. It is the opinion of the Committee that as the years go by and the volumes become antiquated as records of engineering achievement, their inventory value should be diminished by ten cents per annum per volume, so that at the end of eleven years its inventory value should disappear.

On this basis, of the 5,271 volumes in stock, only 2,794 volumes would be inventoried. On the basis of the foregoing valuation this stock would have a value of $1,786, the earlier volumes being considered to have no inventory value. The Committee has similarly considered that the stock of pamphlets of separate papers, which is considerable, has no inventory value.

V.

With respect to the furniture in the house, your Committee has divided it into two groups, which it has designated as office furniture, and belonging to the conduct of the Society's general work; and into household furniture, which includes the specific equipment of the house for other purposes. The value of the office furniture is estimated at $736.50; the value of the household furniture is called $562.75; making a total valuation of both groups $1,299.25, according to this appraisement.

VI.

The Committee summarizes its findings as follows:

1. The house and lot	$85,000
2. The library	10,000
3. The stock of *Transactions*	1,786
4. Office and household furniture	1,300
	$98,086

All of which is respectfully submitted,

JESSE M. SMITH,
H. H. SUPPLEE.

March 19, 1902.

NEW YORK, January 20, 1902.

Mr. F. R. Hutton, Secretary American Society Mechanical Engineers, 12 *West 31st Street, New York City:*

My Dear Sir: I beg to acknowledge receipt of your letter of January 18th.

In regard to the value of the building and lot, we appraise it at $80,000. If this appraisal is for you personally, there will be no charge for it from us.

With kind regards, very truly yours,

CHARLES E. SCHUYLER & CO.

P. S.—I have inquired among several friends who are operating in this section, and they believe it to be a fair and conservative valuation of the property.

Very truly yours,

CHARLES E. SCHUYLER & CO.
Per M.

NEW YORK, January 13, 1902.

F. R. Hutton, Esq., Secretary, 12 *West 31st Street:*

My Dear Sir: Your favor of the 11th inst. is received. The property belonging to your Society on Thirty-first Street is probably worth about $75,000 to $80,000, considered as a marketable piece of property. Of course conditons of adjoining ownership, where parties specially desire your premises, might enable you to get a considerably higher figure, and in the same way something injurious adjoining your premises might make it worth less; but considered merely as an independent piece of property, we think the value that we have given would be approximately correct.

Yours truly,

H. H. CAMMANN.

NEW YORK, January 20, 1902.

F. R. Hutton, Esq., Secretary, 12 West 31st Street:

My Dear Sir: Your favor of the 18th inst. is received. The value which we placed upon No. 12 West Thirty-first Street covered the land and the building. The building practically has not very much value, although it might enable a purchaser to get rent from the property for a few years in case he did not desire immediately to build on the lot.

Yours truly,

H. H. CAMMANN.

NEW YORK, January 22, 1902.

Mr. Jesse Smith, St. Paul Building, New York, N. Y.:

Dear Sir: Referring to the valuation of the Thirty-first Street property, I am advised by a real estate friend, that, in his judgment and that of three of his friends who are familiar with property in that vicinity, that it is worth $90,000. He says three 25-foot lots have recently been sold in the street for $75,000—or $25,000 per lot; that, in his judgment, the value will gradually increase.

Yours truly,

STEPHEN W. BALDWIN.

APPENDIX VIII.

REPORT OF THE FINANCE COMMITTEE.

The Finance Committee respectfully present the following financial statements designated as Sheets A, B, and C, which have been examined and approved by a chartered public accountant. They present also a series of computations showing the cost per paying member from 1894 to 1902, and an estimate of the probable receipts and expenditures for the ensuing fiscal year.

Respectfully submitted,

FINANCE COMMITTEE.

SHEET A.

STATEMENT OF CASH ACCOUNT.

FISCAL YEAR 1901-2.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS AND MECHANICAL ENGINEERS' LIBRARY ASSOCIATION.

September 30, 1901, *to October* 1, 1902.

DR.

1901 Oct. 1.	To Cash on hand		$1,458 14
1902 Sept. 30.	" Cash receipts during year	$44,246 66—	44,246 66
	" Cash borrowed from East River National Bank, New York, N. Y.	14,000 00	
"	" Cash receipts, Trust Funds of Mechanical Engineers' Library Association, Fellowship and Sinking Funds of said Association	1,053 98—	15,053 98
			$60,758 78
1902 Oct. 1.	To Cash in Bank:		
	East River National Bank.	$83 55	
	Fifth Avenue Bank—Trust Funds	99 00	
			182 55

CR.

1902 Sept. 30.	By Disbursements for Expenses of Fiscal Year 1901-2	$39,879 64	
"	" Disbursements for Expenses of Fiscal Year 1900-1	14,696 59—	$54,576 23
"	" Payment of Note to East River National Bank, New York, N. Y.	6,000 00—	6,000 00
			$60,576 23
"	" Cash in East River National Bank	83 55	
"	" Cash in Fifth Avenue Bank—Trust Funds	99 00	
			182 55
			$60,758 78

SHEET B.

COMBINED STATEMENT.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS AND MECHANICAL ENGINEERS' LIBRARY ASSOCIATION.

INCOME AND EXPENDITURE ACCOUNT, *September* 30, 1902. FISCAL YEAR 1901-1902.

INCOME.

Sales Account—Publications	$3,236 41	
" " —Badges	902 50	
" " —Certificates	1 50	
" " —Electros	110 67	
" " —Duplicate Books	26 50	
		$4,277 58
Initiation Fees		4,485 00
Dues—Collected Fiscal Year 1901-2	$27,964 91	
" —Outstanding and considered good, Fiscal Year 1901-2	2,555 00	
		30,519 91
Life Memberships		3,600 00
House Income, Rent—		
For Sleeping Rooms	$2,078 83	
" Hall	415 00	
Total Receipts from Rent 1901-2		$2,493 83
Increase Stock of Transactions on Hand—		
Volumes Received Fiscal Year 1901-2	$8,010 00	
Less—		
Volumes Distributed to Members, Sold and Exchanged for Books and Papers for Library, Fiscal Year 1901-2	7,536 00	
		474 00

EXPENDITURE.

House Account—			
Lighting	$547 59		
Fuel	247 25		
Janitor's Supplies	143 97		
Laundry	437 97		
Insurance	45 13		
Wages	1,740 00		
Incidentals	156 35		
Total Cost of Operating House		$3,318 26	
Interest on Mortgage		$1,402 50	
Repairs and Renewals—			
House	340 00		
Furniture	130 64		
		$470 64	
Depreciations—			
House Furniture	130 00		
Heating and Vent. App.	400 00		
		$530 00	
Total Expense of House exclusive of Interest on Value of Equity			$5,721 40
Certificates and Introduction Cards, including Distribution			172 25
Badges—			
Purchase and Distribution			928 33
Transactions, including Distribution—			
Volume xxii., 1900-1, Part Cost	$8,602 70		
Volume xxiii., 1901-2, Part Cost	7,920 46		
			16,523 16
Committees			2 79
Circulars, including Distribution—			
Admission		$4[illegible]	

Meetings—		
Annual, December 1901	$693 07	
Spring, May 1902	356 55	
		$1,049 62
Catalogues—		
Large Issue January 1902	$548 20	
Small Issue July "	454 38	
Distribution of both	248 40	
		1,250 98
Office Account—		
Salaries	$9,440 00	
Stationery and Printing	390 74	
Postage, general	550 71	
Telegraph and Telephone	86 85	
Supplies	264 05	
Incidentals	152 57	
		10,884 92
Library Expense Account—		
Book Purchase and Binding	$458 80	
Expenses	45 63	
Salary of Librarian	600 00	
		1,104 43
Second-hand Volumes A. S. M. E. Transactions Bought		6 00
Interest on Loans		388 55
Legal Expenses & Expert Fees—		
Expert Accountant $550 00		
Other Expenses 114 00		664 00
Electros for Distribution		165 30
Bad Debts—Written Off		35 52
		$40,504 45
Balance—		
*Excess of Income over Expenditures, Carried to Surplus Account		5,345 87
		$45,850 32

$45,850 32

* If the resolution of the Council, page 4, No. 7, had been carried out this year, whereby only 10 per cent. of the amount received from Life Memberships and Initiation Fees, should be used for current expenses, and the remaining 90 per cent. transferred to a sinking fund, this balance sheet would have shown a deficiency in place of an excess—that is:

Receipts from Life Memberships, 1901-2	$3,600 00
" " Initiation Fees	4,485 00
	$8,085 00
Deduct 10 per cent., the amount which under the resolution would alone be applicable to "current expenses"	808 00
Amount that would have been transferred to a sinking fund if we had been able to carry out this resolution instead of applying the whole of such receipts to meet the expenses of the year	$7,277 00
Excess of income over expenditure, as per Sheet B above	5,345 00
Deficiency for the year 1901-2, if total amount received from Life Memberships and Initiation Fees had not been applied to current expenses	$1,932 00

SHEET C.

COMBINED BALANCE SHEET.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS AND MECHANICAL ENGINEERS' LIBRARY ASSOCIATION.

September 30, 1902. FISCAL YEAR 1901-2.

Assets.

Property, 12 West 31st Street, N. Y., present value appraised		$85,000 00		
Less Mortgage		33,000 00—	$52,000 00	
Fixtures and Furniture—Heating and Ventilating Apparatus	$4,000 00			
Less 10% depreciation	400 00—	3,600 00		
House Furniture, Value appraised Oct. 1, 1901	1,300 00			
Less 10% depreciation	130 00			
	$1,170 00			
Add for new furniture purchased 1901-2	44 50			
		1,214 50—	4,814 50	
Library, books, pamphlets, etc.—				
Appraised Value, Sept. 30, 1901		$10,000 00		
Additions during Fiscal Year 1901-2		315 70		
Book Value, Sept. 30, 1902			10,315 70	
Stock of Transactions			15,495 00	
Stock of Badges			153 00	
Arrears of Dues—				
Fiscal Year 1900-1901		30 34		
" " 1901-1902		2,555 00		
			2,585 34	

Liabilities.

East River National Bank, Loan Acc't		$8,000 00
J. J. Little & Company		597 00
Interest on Mortgage Accrued		350 62
Advance Payments other than Dues		99 45
Advance Payments, Dues		78 45
Trust Funds Mechanical Engineers' Library Association		1,101 23
Surplus Account—		
Balance Sept. 30, 1901	$73,863 02	
Amount Credited to Cash Account on Balance Sheet of September 30, 1901 and since transferred to credit of Trust Fund of M. E. L. Assn. (see foot-note, Tabular Statement on page 35)	569 23	
Corrected Balance	$73,293 79	
Arrears of Dues Outstanding, Sept. 30. 1901, written off by resolution of the Executive Committee, Sept. 30, 1902.	2,215 85	
Balance as finally revised.	$71,077 94	
Excess of Income over Expenditure during Fiscal Year 1901-2 (see Sheet B)	5,345 87	
Surplus, Sept. 30, 1902		$76,423 81

Arrears of Trust Funds—			
Sinking	50 00		
Fellowship	9 00		
		59 00	
Interest on Loans Paid in Advance		96 19	
Insurance Paid in Advance		180 76	
Sundry Debtors—Due the Society:			
For Publications—Volumes and Pamphlets	$216 35		
" Hall Rent	25 00		
" Room Rent	21 50		
" Badges	4 50		
" Electros	5 25		
" Postage	80		
		273 40	
Suspense Account (over-due accounts)—			
For Room Rent	120 92		
" Publications—Volumes and Pamphlets	75 90		
		196 82	
D. Van Nostrand Co.—Exchange Account. Balance due Society for publications		287 80	
Engineering Magazine—Balance due Society for publications		10 50	
Cash.			
East River National Bank	$83 55		
Fifth Avenue Bank, Fell. & Sink. Fund.	99 00		
		182 55	
		$86,650 56	$86,650 56

Having audited the above Balance Sheet and accompanying Accounts, prepared by Mr. Francis W. Hoadley, with the books and vouchers of the Society, we certify that the same, in our opinion, fully and fairly represent the condition of the Society at September 30, 1902.

(Signed) SARGENT, PAGE & TAYLOR,
Chartered Accountants.

NEW YORK, *November* 10, 1902.

COST PER MEMBER, 1894–1902.

YEAR.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1902–3.
Payments A. S. M. E.	$26,143	$27,455	$28,683	$29,078	$28,337	$31,755	$32,439	$39,605		
" M. E. L. A.	3,098	3,281	3,554	3,214	3,550	970	954	813		
Total payments	$29,241	$30,736	$32,237	$32,292	$31,887	$32,725	$33,393	$40,418	$37,454	
Total membership	1,650	1,690	1,685	1,762	1,823	1,861	1,957	2,132		
Paying membership	1,419	1,439	1,440	1,442	1,599	1,600	1,762	1,887	2,095	
Expended per paying member	$20.60	$21.36	$22.30	$22.30	$19.92	$20.45	$18.95	$21.41	$18.19	
Increase in membership	......	20	1	2	157	1	172	165	172	

ESTIMATED RECEIPTS AND EXPENSES, FISCAL YEAR 1902–3.

October 1, 1902, *to September* 30, 1903.

Estimated Receipts.

Sales Account—Publications	$3,000		
" " —Electros	100		
Dues Account	31,000		
House Account—Rentals	2,400		
Total Estimated Receipts exclusive of Initiation Fees		$36,500	
Deficiency		1,042	
			$37,542

Estimated Expenses.

House Account	$3,325	
Interest on Mortgage	1,402	
Repairs and Renewals	900	
Certificates and Introduction Cards	175	
Transactions	15,000	
Circulars	1,800	
Meetings	1,200	
Catalogues	1,300	
Salaries	9,440	
Office Account	1,500	
Library Expenses Account	1,100	
Interest on Loans	300	
Library—Book Purchase	.....	
Committee Work—Research, etc.	.....	
Legal Expenses and Expert Fees	100	
		$37,542

The Council has also directed the distribution of the following tabular statement prepared by Mr. Francis W. Hoadley, Accountant for the Society.

TABULAR STATEMENT OF CHANGES IN ASSETS AND LIABILITIES,

AMERICAN SOCIETY OF MECHANICAL ENGINEERS AND MECHANICAL ENGINEERS' LIBRARY ASSOCIATION COMBINED.

September 30, 1902, *compared with September* 30, 1901.

Designed and compiled by Francis W. Hoadley, Asst. to Treasurer, and Accountant. Showing whence arise the gains and losses in the financial condition of the Society, as affecting its Assets and Liabilities.

Accounts.	Assets and Liabilities.				Losses and Gains.	
	September 30, 1901.		September 30, 1902.		During Year 1901-2.	
	Assets.	Total.	Assets.	Total.	Losses.	Gains.
Property—12 West 31st Street, Equity	52,000 00		52,000 00			
Fixtures and Furniture—						
Heating and Ventilating Apparatus	4,000 00		3,600 00		*400 00	
House Furniture	1,300 00		1,214 50		†85 50	
Library—Books, Pamphlets, etc.	10,000 00		10,315 70			315 70
Stock of *Transactions* on Hand	15,021 00		15,495 00			474 00
Stock of Badges on Hand	144 00		153 00			9 00
Arrears of Dues	4,622 23		2,585 34		‡2,036 89	
" " Sinking Fund	40 00		50 00			10 00
" " Fellowship Fund	9 00		9 00			
Interest on Loans Paid in Advance			96 19			96 19
Insurance Paid in Advance	31 89		180 76			148 87
Due from Sundry Debtors.—Publications	29 20		216 35			187 15
" " " " Hall Rent	25 00		25 00			
" " " " Room Rent	68 85		21 50		47 35	
" " " " Badges			4 50			4 50
" " " " Electros			5 25			5 25
" " " " Miscellaneous			80			80
Suspense Account (Overdue)—Room Rent			120 92			120 92
" " " Publications			75 90			75 90
D. Van Nostrand & Co.—Exchange Account, Bal. due Society	283 05		287 80			4 75
Engineering Magazine—Balance due Society			10 50			10 50
Cash, East River National Bank, N. Y.	889 91		83 55		805 36	
Cash, Fifth Avenue Bank, N. Y.—Sinking Fund	569 23		99 00		470 23	
Total		$89,032 36		$86,650 56		

	Liabilities.		Liabilities.			
Loans from East River National Bank			8,000 00		8,000 00	
Bills Payable	10,673 77					10,673 77
Reserved for Salaries and Wages Accrued	966 68					966 68
Reserved for Interest on Mortgage Accrued	350 62		350 62			
Advance Payments—Other than Dues			99 45		99 45	
Advance Payments—Dues			78 45		78 45	
Trust Funds, Mechanical Engineers' Library Association—						
Fellowship, Balance to Credit of Fund			179 00		179 00	
Sinking, " " " " "	569 23		922 23		353 00	
Accounts Payable	3,178 27		597 00			2,581 27
Total		15,738 57		10,226 75		
Surplus, Sept. 30, 1901		$73,293 79				
§ Surplus, Sept. 30, 1902		76,423 81		$76,423 81		
Total Increase						$15,721 25
" Decrease					12,591 23	12,591 23
Net Increase in Assets, Including Total Receipts from Initiation Fees and Life Memberships		$3,130 02				$3,130 02

* 10 per cent. depreciation written off. † 10 per cent. depreciation written off, and amount expended on new furniture added.

‡ Due to writing off old accounts carried forward from former years but not thought collectable. All of the present balance is believed to be collectable.

§ Explanatory Note.—The balance sheet of September 30, 1901, has been corrected by transferring from assets to liabilities the sum of $569.23, which was incorrectly included in the cash on hand in that balance sheet without offsetting it by a corresponding charge to liabilities as a debt due to the trust fund of the Mechanical Engineers' Library Association.

The Tabular Statement shows the financial condition at the beginning and the end of the fiscal year 1901-2, the changes in each of the accounts due to the transactions of the year, and resulting changes of assets and liabilities.

These may be summarized as follows:

Surplus September 30, 1901 (as reported)	$73,863 02	
Less correction as explained above	569 23	
Corrected Surplus, September 30, 1901		$73,293 79
Excess of Income over Expenditure, fiscal year 1901-2		5,345 87
		$78,639 66
Arrears of dues considered as a good asset at September 30, 1901, and thus included in Surplus at that date, but since considered uncollectable and written off		2,215 85
Surplus, September 30, 1902		$76,423 81
That is—		
Excess Income over Expenditures 1901-2 (as per Sheet B)		5,345 87
Less amount written off, arrears of dues considered uncollectable as explained above		2,215 85
Net increase in Assets		$3,130 02

The Council has also taken action since the first draft of the report on the following questions:

The Committee provided for by resolution at the Boston Meeting to consider and report upon the question of Standard Proportions for Machine Screws, from seven-sixteenths of an inch downwards, has been chosen by the Council and consists of Messrs. Wilfred Lewis, Chairman, George M. Bond, H. K. Jones, John Riddell, George R. Stetson, and C. C. Tyler. The Council has given favorable consideration to the proposition for a Committee on Standard Specifications for Steel Forgings and Steel Boiler Plate. This Committee was later appointed to consist of Messrs. H. W. Spangler, Chairman, E. S. Cramp, Wm. Kent, Geo. S. Morison, and Arthur M. Waitt.

The Council has acted on the request from a Committee on Organization, who had been engaged in elaborating the details for the award of a gold medal for conspicuous achievement in science or industry, as a memorial of John Fritz, Honorary Member of this Society and a Past President. The organization provided that this award shall be made each year by a Commission or Board of Award, who shall also be Trustees of the medal fund. This Board is to consist of sixteen members, four chosen by each of the four national engineering societies now in existence, and with terms of office such that the term of office of one member of each group shall expire at the end of each year. Under the provisions of this organization, the Council of this Society has appointed the following members of this Board:

S. T. Wellman, to serve for four years,
Robert W. Hunt, to serve for three years,
John E. Sweet, to serve for two years,
Gaetano Lanza, to serve for one year.

The Council has also directed the Secretary to proceed to carry out the details for the holding of monthly reunions, during the coming winter, in New York City, for the discussion of papers and topics of engineering interest.

By direction of the Finance Committee, the accounts as published in the statements of the Finance Committee and the Society's accountant, have been scrutinized by a chartered public accountant, and the firm of Sargent, Page & Taylor, who have performed this duty, and have certified to the correctness of the statement as printed in the report of the Council. After the reading of the Report of the Council, the Report of the Tellers, appointed to scrutinize the ballots for members, cast in advance of the meeting, was presented as follows:

AS MEMBERS.

Adams, Edward M.
Backlin, Axel F.
Bayley, W. D.
Bernard, James L.
Boland, Fred'k A.
Brett, Henry E.
Brown, J. Grove
Brown, Jno. J.
Brown, Jno. L.
Bryant, Frank J.
Carew, C. J.
Comstock, L. C.
Cotton, Geo. G.
Dalton, Wm.
Davenport, E. W.
Dawes, H. N.
DeLamater, O. R.
Doughty, A. J.
Emmet, Wm. L. R.
English, Wm. T.
Ferguson, H. A.
Fitch, C. E.
Flint, Walter
Gates, P. W.
Gazzam, Jos. P.
Gifford, R. L.
Hills, Burton U.
Hunt, Chas. B.
Hurd, Chas. H.
Jackson, W. W.
Keyes, Fredc. H.
Lemon, Jno. C.
Lepper, Jno. G.
McGregor, Jno. A.
McNairy, A. B.
Moore, Allen H.
Morford, Thos. H.
Pennington, Jas. H.
Platt, Wilber O.
Robb, Aubrey, G.
Roe, Joseph W.
Sherman, M. H.
Sponsel, C. W.
Stevens, Jno. A.
Stott, H. G.
Thurston, Geo. H.
West, Arthur
Witte, Herman F.
Wood, Wm. H.

PROMOTION TO FULL MEMBERSHIP.

Bailey, Chas. L.
Davis, Robert G.
Morgan, R. L.
Rice, Arthur L.
Sangster, Wm.
Shallenberger, L. R.
Torrance, Henry, Jr.

AS ASSOCIATES.

Barbour, Geo. H.
Chalmers, W. J.
Emerson, R. W.
Gaehr, David
Hill, Alfred J.
Humphreys, Walter
Hurlburt, A.
Kellemen, H. F.
Sachers, R. J.
Williamson, L. A.

PROMOTION TO ASSOCIATE MEMBERSHIP.

Boyer, Edwin S.
Powell, E. H.

AS JUNIORS.

Ahrnke, H. P.
Bain, Benj. F.
Baldwin, J. E.
Beall, F. F.
Brissel, Frank M.
Brisley, E. B.
Eberhardt, H. J.
Eicks, Carl F.
Fennell, Benj. C.
Gordon, Rea M.
Hale, Fred'k J.
Higgins, Jno. W.
Huning, Arno E.
Ireland, M. G.
Isham, Henry S.
Kerr, Eugene W.
Latta, M. Nisbet
Lewman, Everett A.
Lindquist, E. W.
Lodetti, F. E.
MacKenzie, D.
Major, Chas. C.
Pendleton, Frank E.
Perry, Frank B.
Richardson, H. S.
Ruckes, Jos. J., Jr.
Swanberg, F. L.
Taylor, F. W., Jr.
Van Horne, J. R.
Wales, R. A.
Williamson, A.
Young, Chas. D.
Young, Jno. M.

REPORT OF TELLERS.

The undersigned were appointed a Committee of the Council to act as Tellers, under Article 11 of the Rules, to scrutinize and count the ballots cast for and against candidates proposed for memberhip in their several grades in the American Society of Mechanical Engineers, and seeking election before the XLVIth meeting, New York, 1902.

They have met upon the designated day, in the office of the Society, and have proceeded to the discharge of their duty. They would certify for formal insertion in the records of the Society, to the election of the following persons, whose names appear on the appended list, in their several grades.

There are 49 members elected, 10 associates and 33 juniors, making a total increase of 92 names.

There were 482 blue ballots cast, of which 3 were thrown out because of informalities. The tellers have considered a ballot as informal which was not endorsed.

CHARLES H. CORBETT,
D. S. JACOBUS,
A. M. WAITT.
Tellers of Election.

This report was received and ordered on file.

The Chair then called for the Committee on Rules and Methods, appointed at the Boston Meeting. This report was presented by Mr. Charles Wallace Hunt, its Chairman.

Mr. Hunt.—Your Committee has had the subject referred to, under consideration since the general meeting in Boston, and have made a preliminary draft of Constitution and By-Laws, which they still have under consideration. They present, therefore, the following as a preliminary report.

REPORT OF THE COMMITTEE ON RULES AND METHODS, A.S.M.E.

The Committee on "Rules and Methods" begs leave to report that immediately after its appointment at the Boston Meeting of the Society, a meeting of the Committee was held, and circular letters were sent out to the members, asking for such suggestions as would assist the Committee in the work of revising the Rules and Methods of the Society. The summer vacation season prevented other meetings being held until the seventh of October. At this meeting there were twenty-six communications and suggestions relating to the work of the Committee, in reply to the circular letter sent out in June. As some of the correspondents wished to appear before the Committee in person, a special meeting of the Committee was held, and several members appeared and presented oral explanations of the changes in the Rules, which they had suggested.

The meetings of the Committee which have been held since have been employed in rearranging the order of the present Rules of the Society, and formulating clauses or sections to embody such additions, changes or rules as immediately commended themselves to the Committee.

A very thorough examination of our present Rules has been made. These, with such self-evident verbal or other changes, have been typewritten in a convenient form for further consideration, but there are important points which have been left for more careful consideration by the Committee, as it was thought best to devote whatever time was then available to the consideration of the general phraseology and arrangement of the Constitution; and when this had been approximately completed, to then take up a discussion of those important matters which we now wish to bring before this meeting.

The Committee desires to ascertain the wishes of the membership of the Society in relation to several subjects hereafter enumerated. Its object is to embody perfectly in the draft of the Constitution the wishes of the majority of the members of the Society, so far as they can be ascertained by correspondence, by conference and the discussions at the present meeting which we hope will be especially helpful in reaching a conclusion on the various points on which the Committee seeks light.

QUERY No. 1.

Shall the dues paid by Juniors increase from year to year until they reach the same amount as those of Associates or Members?

QUERY No. 2.

Shall the Society have Life Members? If so, shall the fee be increased? If the fee be increased, shall it be the same for all ages, or shall there be a provision that younger persons pay a larger amount than the older ones?

QUERY No. 3.

How many adverse votes shall defeat the election of a candidate for membership in the Society? If a second ballot be taken, how many adverse votes shall then defeat an election?

QUERY NO. 4.

Shall the Treasurer be a member of the Council of the Society ?

QUERY NO. 5.

Shall the Past Presidents continue to be members of the Council? If they remain in the Council, shall all or only a limited number remain?

QUERY NO. 6.

How many members should constitute a quorum at the Annual Meetings of the Society ?

QUERY NO. 7.

Shall the Constitution of the Society prohibit the endorsement of commercial or other schemes or standards?

QUERY NO. 8.

Shall the Constitution of the Society give power to the Council to permit the organization of sections or groups of members of the Society for professional meetings—these groups to be either geographical or professional as the circumstances require ?

A complete review of all matters under discussion, relating to the Rules and Methods of the Society, requires such extended consideration that it has been impossible for the Committee to make a final report within the time specified in the resolution authorizing its appointment. It can now report progress, and ask to be continued until the next meeting of the Society, when they will have their work completed, and present a complete draft of a Constitution, By-Laws and Rules.

C. W. HUNT,
JESSE M. SMITH,
D. S. JACOBUS,
Committee on "Rules and Methods," A.S.M.E.

December 3, 1902.

In comment on the work which the Committee has in hand, I would refer to the proposed plan whereby the present Rules under which the Society has been conducted since 1894, have been divided into three groups. The first will be called the Constitution, and will contain those parts which are fundamental and when once adopted shall be difficult to change. The process of change shall be after due deliberation and discussion by means of a letter ballot. The execution of these fundamental principles embodied in the Constitution will be put in a separate division, which will be designated By-Laws. These can be changed more easily than a Constitution, and it is suggested that the Council, after due notice and discussion on the subject, shall have authority to revise them. In addition to the Constitution and By-Laws a third division shall consist of Rules, which can be changed by the Council at any meeting.

If there is any part of the present draft which members would like to hear, I shall be glad to read it.

The Committee hopes that the meeting will continue it that it may correct its draft in the light of discussion which is now to take place, so that it may report a final draft at the spring meeting of the Society for the consideration of members.

On motion it was ordered that the report be received and the Committee continued.

Mr. George L. Fowler.—I would like to ask whether the Committee has itself prepared answers to the questions which it has embodied in its preliminary report.

Mr. Hunt.—No, sir. It has not answered them. They have been discussed and on some of the subjects a draft has been formulated, but we are open to change the draft in the light of any discussion which may occur here. If any member has any suggestion to make the Committee will be very glad to hear it, as we appear here as learners, and not as teachers.

Mr. George L. Fowler.—I would like to ask what position the Committee have taken in regard to the question of the adoption by the Society of standards.

Mr. Hunt.—The practice of the Society, which results from a long and earnest discussion (in 1886, I think), was that the Society will not, as an organized body, adopt any standards, or rules of any kind. That is now, and has been since that discussion, the unwritten law of the Society. When a Committee makes a report on a subject which in commercial organizations would be approved or adopted as a standard, that report is received by the meeting at which it is presented and is ordered, printed as part of the *Transactions*, to have such weight and authority as the Committee carries, by reason of the arguments and opinions which they have presented. The draft of your Committee embodies this unwritten law in the Constitution.

Col. E. D. Meier.—I trust that the Committee will arrange to have the full draft of its report printed and distributed to the members at least three months before the convention in the spring.

Mr. Gus C. Henning.—It may be desirable to give the Committee a little longer time for the preparation of their final report, so that I would move as an amendment that the Committee be requested to report not later than two months before the date upon which this report is to be presented to the membership and distributed to all members.

On motion this resolution was carried.

The Report of the Committee was then declared open for any further discussion which members might desire to offer upon the topics which it covers.

Mr. Jesse M. Smith presented the following:

Mr. Jesse M. Smith.—I wish to present as an individual some considerations in regard to the dues of Juniors. I have made an investigation for the Committee on Rules and Methods, of the Junior membership of the Society, which I think will be of interest to this meeting. In the Catalogue of January, 1902, there are the names of 531 Juniors. One-third of these, or 177, have been in the Society for 7 years, or longer, varying from 7 years to 20.5, or an average of 10.13 years. This Society has the distinction of having some gray-headed Juniors. Two-thirds of the Juniors, or 354, have now been in the Society less than 7 years, averaging from 1 to 7 years, and the average is 3.08 years. It has been suggested that the annual dues of the Juniors should be gradually increased until they become equal to those of Members or Associates, which are now $15.00. It has been proposed to have the Juniors pay $10.00 a year for the first 2 years, and $1.00 additional each year for 5 years. So that after 7 years they would be on the same paying basis as other members. Upon this basis the 177 Juniors who have been in the Society 7 years or longer should now pay an additional fee of $5.00 per year, or $885 annually. Upon the same basis the 354 Juniors who have been in the Society, on an average of 3.08 years, should pay an average of $1.08 additional, or $382; or a total for these two classes of $1,267 per year of increased income of the Society at this time. This sum would increase gradually to $2,655 per year, when all of the 531 Juniors have been in the Society 7 years. The number of Juniors is constantly increasing, and, including those elected at this meeting, reaches 560 members. I have great faith in the Junior membership of this Society, and I believe when the Juniors realize the situation they will come forward as young American citizens do, and put themselves on the same basis as other members who have been supporting the Society for many years. It seems entirely unreasonable that any man could remain a Junior member for 20.5 years, and it seems rather unreasonable that one should remain a Junior member for 10 years.

Now, in order to bring this question before the Society, and that we may have the question discussed, I have proposed this resolution in general terms, so that a full discussion may be had, and we may get some more definite idea of what is needed:

Resolved, That it is the sense of this meeting that the annual dues of Junior members should be gradually increased until they become equal to those of Members or Associate members.

A Member.—I second that resolution.

The Chairman.—Gentlemen, you have heard the remarks and resolution presented by Mr. Smith, and duly seconded. This is intended to get an expression of opinion for the guidance of the Committee on Rules and Methods in their future work. Are there any remarks upon this resolution?

Mr. James M. Dodge.—Would it not be well to incorporate into that resolution, that when the dues of a Junior reach those of a member, that shall constitute his membership in the Society, without further action of the Council. What I mean is, that that fact alone shall constitute a Junior a member or an associate member. As it is now, they have to be presented again and voted upon. I think it would be well to engraft in that resolution this fact. I see Mr. Smith shaking his head. Perhaps he doesn't agree with me. How is that, Mr. Smith?

Mr. Smith.—No, sir.

Mr. Dodge.—Well, I think it would be well when the dues of any Junior member are equal to those of a Member or an Associate, that that alone should constitute his membership in the Society, without further action on the part of the Society.

Mr. Gus C. Henning.—It has been the custom of the Society to regard the Junior membership as a period of probation and that Junior members passing the age limit of thirty years should be nominated for full membership, provided they were eligible to such promotion from the character of their professional work. If the rate of the annual dues is made progressvie it will cause the Secretary's office and the accountant a great deal of trouble. As it is now, before a member is accepted by promotion, he makes his application and the Society votes whether he is eligible or not. I do not see why, because a man pays a higher rate of due that by this fact alone his membership or his standing in the Society should be raised. It is not a payment of dues which covers the grade of membership but his character and reputation. In my opinion, the membership should always pass upon the qualifications of a man when he seeks full membership.

What I would suggest would be that the Council should notify all Juniors when they have reached the age of thirty, that they are then expected to assume full membership in the Society, and if they do not do so that they no longer remain Juniors, or in any relation to the Society.

In view of this opinion I would propose the following amendment:

Resolved, that it is the sense of the meeting that, hereafter, the date at which a man becomes eligible for full membership should be so fixed that, upon the arrival of a Junior member at that age, he should be notified by the Council concerning the proper steps to be taken in order to assume full membership; the names of such persons shall then be presented as candidates for full membership and shall be voted on in the same way as the names of any new candidates.

A Member.—It seems to me that as the matter stands now it is not very complicated. If a Junior member wishes to continue his membership and pay the increased dues, that is his business. If he is eligible to advancement we are glad to advance him, and the rate of his dues is a mere matter of bookkeeping. Our accountant is certainly able to keep track of the dates at which members join the Society, and the question of charging him with an increased rate of dues becomes a simple matter of record without correspondence or other embarrassment.

Mr. Henry R. Towne.—I understand that the motion aims merely to get an expression of an opinion from this meeting. Now, I am thoroughly in favor of Mr. Smith's motion, but I see this difficulty. I think it should include a provison whereby, when the maximum rate of dues is reached, a Junior member thereupon, *ipso facto*, would become an Associate member, unless at that time he makes applicaton to be admitted to full membership, in which case his name should be submitted to ballot. In other words, that he becomes an Associate member at the time his dues reach the full rate, unless he then makes application to become a full member and is accepted as such.

A Member.—I second that amendment.

The Chairman.—An amendment to this resolution has been made by Mr. Towne, and seconded. Are you ready for the question upon that?

Mr. Smith.—I would like to remark that I do not accept the amendment, and I would like to have the meeting vote upon my original motion. My reason for this is that a Junior member may not be eligible even to Associate membership. The qualification for Associate membership is higher than for Junior, and that for Member is still higher. Now, the Junior may not, in the years that he has been in the Society, have advanced sufficiently so that his qualifications will even be those of Associate member. It seems to me that if his dues are increased, it will behoove him to make application for membership in a higher grade, either Associate or full Member, and that his application should be made in the regular way, the same as any other candidate.

Mr. George S. Morison.—It seems to me that it is worth while in this connection to consider this proposed scheme. I consider that the present Junior members of any society have certain vested rights which the Society cannot fairly take away from them; although it may be able to do it legally by an amendment to the Constitution, it would hardly be fair. On the other hand, it must be remembered that Juniors are usually elected into any society with very much less careful scrutiny than is given to full members or even Associate members. So that to pass, simply on the basis of time, into a higher grade is passing members without very much examination. If we were going to adopt any such plan it seems to me that the proper way would be to elect them full Members at once and provide for a gradual increase of the dues. But the practice in several other societies, on both sides of the Atlantic, is to recognize the Junior member as practically a student on probation. He takes his turn for a term of years. If he becomes an engineer qualified for membership at the end of that term, his name may be considered for advancement like that of anyone else. If he does not, that is the end of it. It seems to me, therefore, that the proper way is to provide that any Junior, when he becomes 31 years old, if that is the age, shall, *ipso facto*, cease to be a Junior, or to be in any way connected with the Society; but that this regulation shall only apply to Juniors elected after the adoption of the revised Constitution and By-Laws.

A Member.—In the Institution of Civil Engineers of Great Britain they have a body of members who are designated as "Students." When such a student reaches the age of 26 years he ceases to be connected with the Institution at all, unless before the time he is rejected his name is sent in to the council for election to the associate grade, and then he is balloted for as a candidate for that grade.

It seems to me that the proposition made by the Committee to increase the dues of Juniors by successive additions is burdensome. I prefer the suggestion of Mr. Morison, that when they reach the age of 31 years they shall drop from the Society, if they are not eligible for Associate membership. I think most Junior members would be glad to be forced into the position whereby they would have to apply for full Membership when they reach the age of 31 years.

A Member.—There is one point which should not be forgotten. The Members and Associates have votes in the management, and the Juniors do not. Therefore, if a Junior is promoted regularly into the upper grade by passing an age limit, we pass him up into the voting grade without a scrutiny. It is quite possible, therefore, that the actual membership of the Society, voted in the usual way, may be entirely over-weighted by the number of members who have not really passed the rigor of being voted for as Members. This should be taken into account in our action.

Mr. C. R. Gabriel.—I would like to ask what disposition Mr. Smith would propose to make of the clause in Article 18, in regard to the extra initiation fee of $10.00 to be exacted from the Junior member in passing to the Senior grade. If I understand the object of this increase of dues, it is to add to the finances of our Society, and if the initiation fee is not exacted I do not see that there would be very much gained. Now, the addition to the dues of $1.00 each year would amount to $15.00 in five years; that would make only an increase of $5.00, if the member is passed from the Junior to the Senior grade without the additional initiation fee. That feature has not been mentioned. I would like to inquire what disposition you wish to make of that?

Mr. Smith.—As I understand it, the initiation fee only comes up when the Junior is passed to a higher grade. If this Junior, who has been in the Society for several years and whose dues have increased to $15.00, wishes to remain a Junior, why, he does not have to pay the $10.00 initiation fee, but, if he wishes to be a full Member and if he is deemed worthy of that honor by the Society, then he has to pay the additional initiation fee of $10.00, which gives him all the privileges of any other Member or of any Associate member.

Mr. Gabriel.—Then the result is that he still remains a Junior member after paying the same dues?

Mr. Smith.—The object is to have all the Junior members pass as soon as possible into the higher grade, if they are desirable, as Members or Associates. If they desire to remain as Juniors and pay the regular dues of Associates or Members, why, that is the Junior's own affair, it seems to me; unless the Society sees fit to drop the Juniors when they come up to the point where they should become either Members or Associate members.

It seems to me that the whole drift of the report I have made is to the point that the Juniors shall gradually assume the responsibility of full Membership as they attain the proper age in the Society; that a man who has been 7 years in the Society, should at the end of that time assume the responsibility of full Membership in the Society.

Mr. F. H. Stillman.—If I understand the object of presenting these motions, they aim to find out the feeling of the Society on this question. It seems to me, however, that instead of motions, we have a series of suggestions no one of which is completely covered by any one of the motions before us. I would move that these motions be referred to the committee with instructions that they include in their report such of them as they deem wise.

Mr. William Kent.—I second this last motion.

Mr. Thomas R. Almond.—Supposing that the man who has made application for Junior membership should be already 30 years of age when he applies. What will you do with such a man when he has been a Junior for 7 years?

The Chairman.—The answer would be that under the policy which has been under discussion such a man would not be eligible to Junior membership in the first place.

Col. E. D. Meier.—Will the Committee read the section of the By-Laws referring to the qualifications and rights of an Associate member.

Mr. C. W. Hunt.—I quote from Article 6 of the present Rules:

"To be eligible as an Associate, the candidate must be not less than twenty-six years of age and must have the other qualifications of a member; or he shall have been so connected with engineering as to be competent to take charge of work and co-operate with engineers."

The Chairman.—The motion is on the question that the resolution presented by Mr. Smith and the amendments which have been made to it, together with this discussion upon them, should be referred to the Committee with instructions that they include in their report their recommendations.

On motion this resolution was carried.

Mr. Gus C. Henning.—The Committee has called the attention of the Society to the great number of Juniors who should already have been promoted to full Membership. I now move that the Council be instructed to send letters to all Juniors who shall have arrived at the age of 31 years, requesting them to apply for full Membership in the Society, beginning with this meeting.

Mr. William C. Brown.—I would like to ask what the alternative would be.

Mr. Henning.—This is a request only, but it would seem to me that when the question is properly presented to the Junior membership, who are eligible, a great many will take advantage of it to become full Members.

Mr. William Kent.—I would suggest as an amendment that the Council append to such a notice that section of our Rules which directs the procedure whereby Junior members shall become full Members of the Society.

A Member.—It would seem to me more sensible to defer action of this sort until the whole question of our By-Laws has been presented by our Committee and discussed by the whole Membership. A Junior member would have a perfect right to say that he did not want to take the action which the Council has been requested to urge on him, and he might even consider it a matter of impertinence on the part of the Council to make such a request. I feel that it is due to the Committee on Rules that we should leave this matter to them, at all events until they have expressed, as a Committee, their opinion concerning an arrangement of this sort. The mere reference of such a resolution as has been presented for action by the Council does not help the Committee out. We will be adding to their burdens rather than trying to lessen them.

It would seem to me to be courtesy and kindness to our Committee to take a vote on the question of the treatment of the Junior membership in order that the Committee may be guided by such an expression of sentiment. If the majority are not in favor of doing anything, such action would be a way of saying so. It seems to me we ought to let the Committee know whether we are in sympathy with their ideas or not, and leave the details to them to work out.

Mr. Gus C. Henning.—My resolution was intended to be a matter entirely distinct from the general questions of policy which we have already, by motion, referred to the Committee. My idea was to present a resolution which should secure $15.00 a year dues from those Juniors who have been Juniors so long that they ought to have been in the Society as Members, and that they should be compelled to make that payment for this year. The work of our Committee will provide a policy for the future when their report is received, but my resolution was intended to be entirely independent of that discussion which we have practically closed by referring the subject of future policy to our Committee.

Mr. Smith.—I arise to a point of order. Mr. Henning has said that this is an entirely separate resolution. Therefore, my point of order is, that it has no bearing upon the resolution that I offered. There are certain amendments which have been offered by Mr. Towne, and I think by one or two others, to my resolution. I request the Chair to put the question upon those amendments, and, if they are carried, then to add them to my original resolution and put the question upon that. I think my resolution is entitled to consideration by the Society, and I request that the Chair put the question upon it.

The Chairman.—I would say that the meeting has voted to refer your resolution to the Committee, having discussed it. I do not see that without a vote to reconsider that action it would be proper to put it before the Society again.

Mr. Kenneth Torrance.—It seems to me that we have not done justice to this Committee in referring the matter back to the Committee as we have. We have had presented two different schemes. One by Mr. Smith, and another, which may be considered, by Mr. Morison, and we have referred those unacted upon back to the Committee. I think there is no doubt that most persons here have an opinion as to which of those two methods is the better one, and I think it would be most fair to the Committee that we should express ourselves about them. Therefore, I would like to move that the action in referring this matter back to the Committee be reconsidered.

The Chairman.—The Chair would inquire if the gentleman voted in favor of the reference to the Committee?

Mr. Torrance.—I did.

The Chairman.—Then you are entitled to move for a reconsideration.

On motion the question concerning the reconsideration of the reference was put and carried. The Chair thereupon announced that the original motion was before the meeting with the amendment by Mr. Smith, as follows:

Resolved, that it is the sense of this meeting that the annual dues of Junior members shall be increased annually until they equal $15.00.

The amendment by Mr. Towne is: That after the increase of the Junior members' dues has become equal in amount to the present dues of full membership, that they shall then either become Associate members or shall apply for election to full membership.

Mr. George S. Morison.—I would like to have the meeting consider my amendment that Juniors elected after the amendments to this Constitution shall cease to have any connection with the Society upon reaching the age of 30 years.

Mr. Kent.—If I understand Mr. Morison's amendment that a Junior, when he becomes 30 years of age, shall cease to be a member of the Society—unless at that time he applies either for Associate or full membership—and also pays the extra $10.00 initiation fee required on such promotion, I would state my concurrence in that idea, because I have opposed Mr. Smith's original motion and Mr. Towne's amendment. I do not believe in the gradual increase of dues, dollar by dollar, nor do I believe in having the Juniors become Associates by automatic process. There have been cases where a man has applied for membership and where he has been rejected by the Council, and where he would have been severely black-balled by the voting membership if the Council had passed him, and yet, five years earlier that man would have had no difficulty in being passed to Junior membership; matters had developed during the interval which made him a person whom the Society did not care to have enrolled as a Member.

With the consent of the movers and seconders, Messrs. Morison and Towne withdrew their amendments, and the question came up on the original proposition of Mr. Jesse M. Smith, that the annual dues of Junior members shall be increased gradually until they become equal to the present dues of Members. The question being put, the motion was lost.

Mr. Morison then presented his original amendment as a new resolution, that Juniors should cease to be members hereafter unless, on reaching the age of 30 years, they should apply for Associate or full membership.

The Chair put this motion and it was carried.

Mr. Jesse M. Smith.—I must rise to ask for information. What becomes under this recommendation and opinion of the Society, of the 560 Junior members now connected with it under the present Rules? May they remain Juniors, paying $10.00 a year, indefinitely? We cannot turn them out under that policy outlined by Mr. Morison, because they have vested rights in the Society.

Mr. Henning.—It was in view of that fact that I offered my original resolution. These Juniors now in the Society under that resolution must abide by the result of their application to be promoted to a higher grade. If these Juniors are acted on favorably they will become Members on reaching the age limit. If they are not elected they are black-balled candidates, and would cease to be members of the Society.

Mr. Henning's motion was duly seconded and was put by the Chair:

Resolved, That Junior members on reaching the age of 31 years shall apply for Associate or full membership in the usual manner, and shall abide by the vote of the Society on their application.

A Member.—It seems to me that this Society has no right to tell a man what he shall do. Every Member desires that every eligible candidate shall desire to come to us with an application for membership, but we have no right to tell him that he must come or serve a penalty.

Mr. James M. Dodge.—Our Rules state that the age limit for the Associate grade is 26 years. It seems to me that a Junior should apply for Associate membership when he is 26, and not wait until he is 30 years old, which has been set as the age for full membership.

Mr. George L. Fowler.—I would like to ask what the Junior members are going to do who are now over 31 years of age, if this meeting declares that a man now a Junior who has passed a certain age limit shall pay $15.00 Junior dues. I think a man in this Society 31 years of age, and unable to pay $15.00, has something wrong about him. If he has to pay $15.00 the chances are that he will apply for higher grades of membership with their rights and privileges. If you make a Junior member who is 31 years old and over pay $15.00 dues, in my opinion the thing will straighten itself out without action by the meeting.

A Member.—It seems to me that we are not quite fair to the Juniors in this discussion; there are a great many of them who are good working members who will hasten to come up and become full Members of the Society if the dues which they pay are raised, and they appreciate the Society's need of their increased payment. I think this discussion will go very far towards reducing the difficulty. Many men who have overlooked the matter of the return which the Society is making to them for their dues, will hasten to become Associates and full Members.

The Chair then put the question on Mr. Henning's resolution that Junior members, on reaching the age of 31 years, shall apply for full membership in the usual manner, and shall abide by the vote of the Society on their application.

The motion was lost.

The next business before the meeting was an action upon the amendments to Article 45 of the Rules concerning the procedure to be followed in making amendments to the Rules as they now stand. The question came up upon the report of the Committee on Rules and Methods, which had considered and reported favorably upon an amendment, in the following form:

To *replace Article* 45 is as follows:

"These rules may be amended by a ballot at any *annual* meeting, by the assent of two-thirds (⅔) of the *members voting, in person, by proxy, or by letter ballot,* provided that written notice of the proposed amendments shall have been given at the preceding regular meeting, and that a blank ballot accompanied by the mover's reasons for the change if he so desires, and a comment on the same by the Council if it so elects, shall have been mailed to each member entitled to vote no later than the time of mailing the ballot for officers of the Society. The ballots shall be voted and the result canvassed in the manner prescribed in Articles 33 and 34. The tellers shall immediately certify the result to the annual meeting, when if the certificate shows that two-thirds of the votes cast are in favor of the amendment, it shall immediately take effect."

Mr. Henry R. Towne.—I wish to offer a resolution that the vote upon all proposed amendments to the Rules shall be by ballot. My motive for making this motion is that the proposed amendment, when sent to all the voting membership, was accompanied by a form of proxy so that all members might express their opinion even if unable to attend the convention at which the vote is to be taken. The Committee have received 96 such proxies, and my motion would be that in order to enable these votes to be taken and counted, the vote upon the amendment shall be taken by ballot.

Mr. Kent raised the point of order that the amendment presented by the Committee could not be considered at this meeting, because it had not been presented in the form recommended by the Committee, as required by the provisions of the Constitution, at a previous meeting. The only amendments which, in his opinion, could properly be taken up to cover a procedure for an amendment to the Rules, were amendments presented by Mr. C. W. Baker at the New York Meeting of a year ago, and amended in Boston by a slight change in phraseology so as to read as follows:

At any regular meeting of the Society any member may propose in writing an amendment to these rules, a copy of such amendment having been filed with the Council at least ten days before the opening of said meeting. Such amendment shall be taken up by the Society at a following session of the same meeting, and shall be subject to discussion and amendment and to final acceptance or rejection by a majority vote of the members present and voting. If it is finally accepted, it shall be submitted to a letter ballot of the entire voting membership of the Society; such ballots to be sent out at the same time as the next succeeding ballot for the election of members. A majority of the ballots cast shall adopt or reject the amendment.

Mr. C. W. Hunt.—Our By-Laws state that action shall be taken on an amendment to the Rules by a two-thirds vote of the members present. The law under which the Society acts states that every membership association can vote by proxy. The courts have decided that phrase, "of the members present," means either present in person or by proxy. There are about 100 proxies here. They have an absolute right to vote, and we have no right to take any move which will practically disfranchise them. It seems to me that this vote can be taken by raising of hands, and then the proxies can be added to the *viva voce* vote. If we must take a ballot on all amendments and the original proposition, it will mean a loss of much time and a great delay.

Mr. Towne.—I will withdraw my motion and second the admirable proposition of Mr. Hunt that the vote of those present shall be taken by show of hands or *viva voce*, and that then the Committee who have received these proxies shall have the opportunity to cast their vote of 96 proxies, or whatever the number may be, before the Chair announces the result.

Mr. C. W. Baker.—I should not think of pressing my amendment in competition with the amendments offered by the Committee on Revision of the Rules, except that it seems to me the Committee has overlooked some points which are important in drafting its amendments. I would like to have the two amendments placed before the meeting on equal footing, so that the members can take their choice between mine and that presented by the Committee.

Mr. Towne.—This subject is one which has been before us all during the last year, and as I have been serving until lately on the Committee on Rules, it is one that I have had occasion to consider very carefully. My views concerning it have changed in the last two days as the result of discovering a defect in both of the pending amendments, which I think has been overlooked, and which, when it is explained to the members, will cause them, I think, to favor some other method of reaching the result which those two amendments aim to accomplish. The existing Rule 45, which is the only provision in our present Constitution for its amendment, does not say that the proposed amendment, but *notice of the amendment* shall have been given at the previous meeting. Now, I believe that this language, fairly construed, opens the door to this meeting for action upon any proposed amendment, so long as it is fairly germane to the scope and purpose of the original notice. Mr. Baker's motion is before us, as I understand, in the form in which he originally presented it, with his Boston revision. No question can arise, therefore, as to a vote being competent to this meeting on that motion. Mr. Miller's motion, also introduced at the Boston meeting, is also before us in its original form, and can be voted upon in that form; and this also is beyond question. Mr. Miller's motion, amended by a transposition of its words but not changed in its substance, has been reported by the Committee on Rules, with its endorsement, and I believe that this is equally before this meeting.

But I want to call the attention of the members to a defect which it seems to me exists in all three of these motions. We have pending before us a proposition to supersede our present Rules. They are not well arranged, and the Committee proposed to bring in, a year from now, a new Constitution, supplemented by By-Laws and probably supplemented by a set of Rules on minor matters. In view of the fact that the fundamental law is to be changed in this way, I beg to suggest that we should do as little tinkering with the present Rules as possible, as the new Constitution and new Rules will probably be in operation in one more year. It is merely important that action should be taken now which will provide a careful and deliberative method of passing upon the proposed new Constitution—the most important legislative matter that the Society has ever had before it.

The proposed amendments by Mr. Miller and by the Committee provide:

These Rules may be amended by ballot at any annual meeting by the assent of two-thirds of the members voting, in person, or by proxy, or by letter ballot, provided that written notice of the propsoed amendent shall have been given at the preceding regular meeting, and that a blank ballot accompanied by the mover's reasons for the change, if he so desires, and a comment on the same by the Council, if it so elects, shall have been mailed to each member entitled to vote no later than the time of mailing the ballot for officers of the Society.

Gentlemen, you see that under this Rule any and every member of the Society can vote upon any proposed amendment to the Rules, and that it is mandatory that every amendment so presented shall be printed and issued, accompanied by a ballot, to the entire membership. At the Spring meeting the Committee expects to report a new Constitution and By-Laws. That will be the time to discuss that Constitution, but every difference of opinion that arises in the course of that debate may, under this proposed Rule, be made the subject of letter ballot, because this proposed Rule confers upon any member the right to demand a letter ballot upon an amendment, stated in his own terms, and the entire membership must pass upon it before it can be disposed of.

Why, gentlemen, we will have a flood of such amendments which will swamp the entire project and tie us up for a year or two!

Now, to overcome this difficulty, and to retain all the other objects sought in the motions of Mr. Baker and Mr. Miller, and in the modification by the Committee on Rules, I submit this resolution:

ARTICLE 45. An amendment to these Rules may be proposed, or a notice thereof be given (and we want at this meeting to take such action or to give such notice as, under this resolution, will make it competent for us to act a year from now, and to act definitely, on the adoption of our new Constitution, and yet to provide ample time and opportunity for discussion, and also to provide that, when it is put before the membership for final vote in the form in which it has been passed by the Spring meeting, it shall come as a concrete question on which the vote shall be simply "yes" or "no") at any annual meeting, by any two members or associates in good standing, and when so presented in writing shall be read to the meeting and may be discussed thereat. A copy of any amendment so introduced shall then be distributed to the memebership, not less than two months before the next ordinary meeting. At the next regular ordinary meeting of this Society such amendment shall be brought up for discussion, and may be modified or amended by a majority vote of the members present, in person or by proxy, at such meeting. After such meeting a copy of the amendment so presented, in the form finally approved or adopted by such meeting, shall be mailed to the membership, as before, accompanied by a ballot by which each member entitled to vote may vote for or against such amendment.

Now, gentlemen, in brief, that Rule means this: That to adopt an amendment to our Constitution or Rules a year hence, a notice of the intention to do so must be given at this meeting, and that some time, not less than two months, prior to our Spring meeting, that amendment, in concrete form, must be put in type and distributed to the whole of the membership, accompanied by a proxy whereby members unable to attend the meeting may delegate the power to vote for them to some other member; that at the Spring meeting the amendment so introduced shall come up for discussion; that the Spring meeting will have absolute control over it; and that that meeting, by the membership there represented in person or by proxy, shall cast the proposed amendment into its final form; whereupon, and at the proper time before the annual meeting, the amendment as thus perfected and adopted by the Spring meeting, accompanied by a ballot, shall go to the entire membership for a simple "Yes" or "No" vote.

The method is simple and clear; it provides that one year shall be taken for any proposed alteration of our fundamental law, and I submit that less than one year is not an adequate time within which to make changes in our law.

Mr. Kent.—I am very glad indeed that Mr. Towne has stated so clearly the argument against the amendment which his Committee propose. I think that he himself, holding these proxies, would now vote them all against that amendment of the Committee. In regard to this new amendment that he proposes, I see some defects in it, and I think that for the temporary purpose of enabling us to vote on the new Constitution when it comes up, there is no serious objection to Mr. Baker's amendment. I think it is the best form that has been proposed. All that Mr. Towne can do now is to propose his amendment at this meeting, and let it be voted on a year hence. But Mr. Baker's amendment is now before us for final passage, and, if passed, it will enable us to change the Constitution as we please by its amendment.

The Chairman.—The Chair would call the attention of the members to the fact, which is a matter of record in our *Transactions*, that Mr. Baker proposed an amendment to Article 45 of the By-Laws at the annual meeting, and again at the Boston meeting he brought the same amendment before the Society with some verbal changes. Mr. F. J. Miller, at the same Boston meeting, also offered an amendment to that same section of the Rules. The Chair would rule concerning this action, brought before the Society under the provisions of the present Section 45, that since it is not stated in the By-Laws that it is necessary to give the full text or wording of a proposition to amend, but merely a notice that an amendment is to be offered for consideration at the annual meeting, there are three propositions before the meeting. A motion to adopt any one of these will place the matter properly before the Society for discussion. These propositions are Mr. Baker's amendment, Mr. Miller's amendment, and the amendment proposed by the Committee on Rules, to which Mr. Towne has made an amendment.

Mr. Kent.—Then I move the consideration and adoption of Mr. Charles Whiting Baker's amendment.

This motion being duly seconded, the matter was before the meeting.

Mr. Baker.—Mr. Towne has stated that he finds the amendment which the Committee proposed to be seriously defective. Now, it was exactly that defect in the Committee's amendment which led me to ask that my amendment should be brought before this meeting, because the defect which he points out does not exist in the amendment I offer. Mr. Smith suggests that the ten days' notice to the Council required by my amendment will delay action on the general amendment of the Rules now pending. That is not so. The action can be taken at any regular meeting, and not at the annual meeting only. The distinguishing feature of the amendment which I have offered as compared with either Mr. Towne's amendment or the Committee's amendment, is that before anything can be sent out by letter ballot, or before the Society can be put to expense for printing anything, it must pass the gauntlet of the Society in convention assembled. That is the point we must be careful about. Otherwise it is within the power of any member to bring in an amendment of unlimited length, and put the Society to the expense of printing it and sending it out to the membership. That is exactly what I want to avoid.

To show how my amendment will operate I will illustrate by taking the pending general amendments to the Society's Rules. It has been proposed that these amendments shall be sent out to the members at least two months before the Spring meeting. Now, there is nothing in my amendment to prevent that. My amendment simply provides that the proposed amendments shall be presented to the Council at least ten days before a regular meeting. If the amendments are put in print, of course that notice will be given. Then these amendments will all come up before the Society at the Saratoga meeting, and it can be discussed there and amended, and the members can put them in any form they think best, and can then either reject them or accept them, and order their submission to the whole membership by letter ballot. The chief point of my amendment is that until a pending amendment is approved by the Society in convention assembled, it cannot be sent out to letter ballot. This, it seems to me, is the reason why mine will prove a better working plan for the Society than either of the other amendments which have been offered.

Mr. Towne.—If the meeting will bear with me I would like to explain the process which I have sought to frame into a rule. It covers these very important facts:

(1) A full year in which to act upon an amendment to the fundamental law. (2) That an amendment, when proposed, must be put in type and distributed to the whole membership at least two months before the meeting, and thus give to those unable to come to the meeting an opportunity of instructing their proxies understandingly. (3) Any amendment so introduced at the Spring meeting shall be open to discussion at that meeting, and shall be put into final form at that meeting. In other words, it shall receive the stamp of approval of so much of the

Society as is represented personally or by proxy at that meeting, and then be boiled down to a concrete form, and that when so reduced to definite form, the amendment shall go out for ballot vote by the entire membership on the simple question of "yes" or "no."

Now, the more you think over what we are trying to do, the more you will find that these steps are each of them essential to the best result in a matter of such fundamental importance, and that the amendment which I have offered for your consideration culls out the good points in all the others which have preceded it. The orderly way, as it seems to me, of acting in this matter, should be to put these several amendments in the order of their presentation; and, if I am correct that the good points of all of them are embodied in the last, vote each one of them down as it comes up, with the intention of then adopting the final one. If that is adopted, it is so worded as to make it feasible at this meeting to give such notice that, at the December meeting, we can act upon the proposed new Constitution.

Mr. Kent.—The object of these amendments is to enable us to amend the Constitution. We should amend the Constitution, if we do it at all, in a perfectly legal way. Some one may raise the point that if we pass Mr. Towne's amendment instead of that which Mr. Baker has presented it would not be legal, because it had not been presented in due form at a previous meeting. Aside from that, Mr. Towne's amendment is presented at this meeting for the first time, and comes to us as something new. I would suggest that he make his amendment a notice of intention to amend the Rules a year hence. That would narrow the present consideration down to Mr. Baker's amendment, to which it seems no reasonable objection has been made.

The Chairman.—The Chair would rule that any substitute or amendment to the original amendment which has been proposed, would be in order if germane to the amendment of which notice was duly given. As the matter now stands before the meeting the question is upon Mr. Baker's amendment, of which he gave notice at New York and Boston.

A decision being called for as the result of the *viva voce* vote, 58 members rose in favor and 38 in opposition to it. The Committee held 94 proxies in favor of the Baker amendment, which it decided to favor, making the total vote in favor of the adoption of Mr. Baker's amendment 152; 38 negative votes added to

2 proxies cast against the amendment, made 40 negative votes in all. The Chairman thereupon announced that Mr. Baker's amendment had been carried by a vote of 152 to 40.

Recess was then taken until half-past two, and luncheon was served in a room adjoining the meeting place.

EXTRA SESSION. WEDNESDAY AFTERNOON, DECEMBER 2D.

The meeting was called to order at 2.30 P. M. by the reading of the Report of Tellers of Election, as follows:

REPORT OF TELLERS.

The Committee of Tellers appointed to count the ballots cast by the members for officers of the American Society of Mechanical Engineers for the years 1902–1903, begs to submit the following report:

Total ballots cast	549
Ballots thrown out unsigned	4
Ballots thrown out signed with rubber stamps	0
Other informal ballots	4
Total informal ballots	4
Total ballots counted by tellers	545

Of the regular ballot counted by the tellers they would report the following result:

FOR PRESIDENT,

James M. Dodge	541
Scattering	4

FOR VICE-PRESIDENTS,

F. H. Daniels, Worcester, Mass	548
Jas. Christie, Philadelphia, Pa	547
John R. Freeman, Providence, R. I	524

FOR MANAGERS,

R. C. McKinney, New York, N. Y	541
S. S. Webber, Trenton, N. J	541
Newell Sanders, Chattanooga, Tenn	514

FOR TREASURER,

F. H. Stillman, New York, N. Y	151
Wm. H. Wiley, New York, N. Y	264
No Choice	130

Our count shows, therefore, the election of Mr. Dodge for President; Messrs. Daniels, Christie, Freeman for Vice-Presidents; Messrs. McKinney, Webber, Sanders for Managers; Mr. Wiley for Treasurer.

Respectfully submitted,

P. M. Chamberlain,
William T. Bonner.

The Chair asked whether Mr. James M. Dodge, President-elect, was in the room, and on Mr. Dodge rising in his place, he asked him if he would accept the office of President to which he had been elected. On Mr. Dodge expressing his acceptance, Messrs. C. W. Hunt and Worcester R. Warner, a special Committee appointed for this purpose, escorted the President-elect to the platform, and Vice-President Waitt from the Chair introduced Mr. Dodge to the meeting and expressed the hope that the cordial co-operation and consideration which had been accorded his long line of predecessors might be continued to him. Mr. Dodge in reply assured the Society of his purpose to perform the duties of his office to the best of his ability and with an eye single to the welfare of the Society.

Mr. Gus C. Henning presented before the meeting a pamphlet embodying a series of resolutions incorporating proposed amendments to the By-Laws, and moved that they be referred to the Committee on Rules and Methods, as follows:

Mr. Gus C. Henning.—A year ago I presented these amendments which I have in my hand, with a veiw to having them considered and discussed. In view of the fact that we have had a considerable discussion on these questions and that we now have a Committee which is instructed to look into these matters carefully, and in time to act definitely on them a year hence, I would like, instead of taking any more time of the Soceity, to present the following resolution:

Resolved, That all proposed amendments to the Rules which have been formally presented during the past year for consideration by the Society, and which have not heretofore been acted on, be now referred to the Committee on Rules and Methods for consideration in connection with the other subjects for the consideration of which the Committee was appointed, and that the membership of the Committee be increased to five members.

This motion being duly seconded, was carried.

The Chair announced at a subsequent meeting the appointment of Messrs. R. H. Soule and George M. Basford as such additional members.

The next order of business was the consideration of the Report of the Committee on Standard Methods for the Conduct of Steam Engine Trials. The report was presented by title by Professor D. S. Jacobus, Secretary of the Committee, and was followed by printed discussions. Mr. Kent, after contributing his suggestions to the Committee, presented a motion that the report be received, printed in the *Transactions*, and that the Committee be discharged with the thanks of the Society.

On motion this resolution was adopted.

Professional papers were then taken up. The first in order was the paper of Mr. Frederick A. Halsey on the Metric System. This paper had been distributed quite widely outside of the Society among those interested, as well as to the membership, and among those to whom this invitation had been extended to participate in the discussion were Dr. S. W. Stratton, Director of the Bureau of Standards at Washington, D. C., and the Hon. J. H. Southard, Chairman of the Committee on Coinage, Weights and Measures of the House of Representatives. The other participants in debate, in writing or verbally, were Messrs. C. R. Gabriel, G. S. Morison, H. H. Suplee, W. S. Rogers, C. V. Kerr, O. C. Woolson, Percy Sanguinetti, E. P. Bates, Spencer Miller, James M. Dodge, Wm. Kent, H. R. Towne, H. D. Sharpe, Fred A. Geier, G. C. Henning, F. J. Miller, Samuel Webber, W. W. Crosby, James Christie, and C. J. H. Woodbury. At the close of the discussion on this paper, as the hour was already late, the meeting adjourned until the following morning.

Fourth Session. Thursday, December 4th.

The meeting was called to order at 10.15 by Vice-President Waitt in the Chair. The first order of business was the presentation of a Report from the Committee of the Society appointed in 1896 to prepare and have in readiness material in opposition to the compulsory adoption of the Metric System. The report was as follows:

To the American Society of Mechanical Engineers.

Your Committee on the Metric System beg to report the following statement and resolutions, and recommend their adoption by the Society.

The common sense of mankind has taught them that in all systems of measurement convenience of forming mental conceptions, convenience of expression, whether verbal or written, convenience of computation and convenience of memory, all require that intervals, distances and dimensions shall be expressed in terms of the largest suitable unit, supplemented by smaller units when necessary.

The circle is divided into degrees, minutes and seconds. Time is expressed in years, months, days, hours, minutes and seconds.

By English-speaking peoples, geographical measurement is expressed in miles, and binary divisions of the mile.

Land measurement is expressed in rods, yards, feet and inches.

In cloth measurement and in civil engineering works our unit is the yard, with its binary divisions .

In monetary divisions, the English employ three units—pounds, shillings and pence.

We have two units—the dollar and the cent.

In all these systems of measurement, the principle observed is to employ the largest unit until it becomes necessary to resort to the smaller ones.

In conformity with this principle, we, in common with all English-speaking people, employ for mechanical measurements two units, the foot and the inch, and divisions of the latter by continual bisection. We employ also decimal divisions of the inch when necessary, but not otherwise, finding the binary divisions more convenient for general use.

It will be observed that in all these systems these units, and also their binary divisions, have distinctive names, and so are presented to the mind as concrete realities.

In defiance of the principle above stated, the metric system requires the designer and constructor of machinery to employ a single unit, and that the smallest possible, the millimetre, nearly .04 of an inch, and to express all dimensions in terms of this unit and to employ the decimal system only.

A comparison of the English and French systems of linear measurement shows as follows:

The French system consists of a single arbitrary unit, the metre and decimal division and multiple of this unit. To this single unit and this single system of division the Metric System is limited.

The English system consists of five units in common use, which are adapted to to different dimensions and distances, from the smallest to the largest; and two systems of division, the decimal system and the binary system.

The decimal system meets all requirements that any decimal system could do, and we are free to employ it wherever we choose. We might apply it to the division of any of our five units, if we saw occasion to do so. Mechanical engineers find it useful principally in the smaller divisions of the inch. Civil engineers employ it in divisions of the foot.

The binary system is found so much the more convenient, that it is employed exclusively to express divisions of miles, rods and yards. The foot we divide into inches. We then return to binary divisions of the inch and employ this system for all ordinary uses, resorting, as already observed, to decimal divisions only when we are obliged to. The two systems work together in perfect harmony.

We find that in linear measurement the proper field of the decimal system is for the expression of small dimensions, or those larger ones that could not be expressed otherwise; for general use it is out of place.

The reason for this universal preference of the binary system lies in this valuable feature. Its smaller divisions are aliquot parts of all larger divisions of the unit, and conversely, the latter are all multiples of the former. It is thus seen to be the natural system of division—continual bisection.

In addition to this, founded upon the interesting relation between the two engineering units, the foot and the inch, we have a remarkable system of scales, the valuable general feature of which is an interrelation similar to that between binary divisions of the unit above noted.

It will be observed that the English system imposes no restriction. We have entire freedom of choice and use the decimal or the binary divisions as we see fit.

These great advantages, palpable to everyone, in the judgment of your committee render it certain that before the close of this century the English system of linear measurement will come into universal use; when the Metric System, so far as measurements are concerned will have disappeared, as its supposed scientific foundation has done already.

In view of the above facts, your committee offers the following resolutions:

First—*Resolved*, that the Mechanical Engineers of this country are the only parties competent to decide intelligently upon a system of measurement most suitable for their own use.

Second—*Resolved*, as for the bill now before Congress, providing that the Metric System shall be the legal system of weights *and measures* in the United States, and making its use obligatory in the government departments, that, so far as it affects mechanical measurements, conceived in ignorance, it is simply absurd.

The meeting seemed unprepared to take action upon the resolutions presented in the report, so that on motion the resolutions proposed by the Committee were laid upon the table by a rising vote, 36 in favor of the motion to lay it upon the table and 22 against it. The Chair declared the motion to lay the report upon the table carried.

It was then moved that the Council be requested to consider the appointment of a committee such as suggested by Mr. James Christie in his paper read at the previous session, upon the general question of the preparation of the arguments for and against the adoption of the Metric System. It was Mr. Christie's suggestion that such a commission should consist of a dozen members, of whom three should be chosen from the American Society of Mechanical Engineers, three from the American Society of Civil Engineers, three from the Association for the Advancement of Science, and three from the New York Chamber of Commerce.

It was suggested that additional members of the commission should be chosen from the American Institute of Electrical Engineers, the Franklin Institute, and the American Institute of Mining Engineers. It was on motion left entirely to the Council as to the choice of the constitution of this Committee. It was suggested that in view of the fact that this Society was more concerned with the matter of measurements and changes in the units of measurement than all other societies put together, that it would be a mistake to bring in representatives of other bodies. The motion, as amended by Mr. Miller, was that the Council be requested and instructed to consider the question of appointment of a committee, as suggested by Mr. Christie in his paper, and if, in its opinion, this would be desirable, to confer with other kindred societies in the matter to bring about the appointment of a joint committee. A rising vote being called for, those in favor of the resolution were counted 34, and those opposed 29.

The Chair announced the motion carried.

In this connection the following resolution was presented and duly seconded:

Whereas, the technical press, in 1902, published statements implying that the American Society of Mechanical Engineers had taken action withdrawing its opposition to the adoption of the Metric System as the standard of weights and measures for the United States and

Whereas, there is no foundation in fact for such statements,

Therefore, *Resolved*, that the society hereby records the fact that at no time has it taken any action reversing its original attitude of opposition to the adoption of the Metric System or susceptible of such interpretation.

In the debate the following explanations were asked and offered:

Mr. James P. Tolman.—May I ask a little further explanation? We have been told that this Society never gave its assent to any standard, and was not to be considered or quoted as favoring a standard in any way. I would like to know what the action of the Society may have been, which it is said herein has never been rescinded?

The Secretary.—It will, perhaps, be remembered by the older members of the Society that at its first meeting in the spring of 1880, Mr. Coleman Sellers of Philadelphia presented a paper urging the arguments against the Metric System. Following that paper a letter ballot of the Society was ordered in the summer of 1880 on the general question—the Secretary does not remember the wording—that in the sense of this Society it is inexpedient to urge the compulsory adoption of the Metric System, and that was carried by the vote of the Society. That was directed to the particular object to which reference has been made, and the Society did put itself on record 22 years ago that it was against the compulsory adoption of the Metric System.

At the conclusion of this explanation and further statements by Messrs. Henning and Halsey concerning the policy of the Society, the resolution was passed.

The meeting then passed to the reading and discussion of professional papers, as follows:

It was on motion resolved that until the convention should catch up with the time table outlined in its docket, the papers should be read by title, so as to give full time and opportunity for their discussion.

Prof. Sidney A. Reeve, on "Entropy Analysis of the Otto Cycle"; "Apparatus for Obtaining a Continuous Record of the Position of an Engine Governor," by Mr. Jos. C. Riley; "Fly Wheel Capacity for Engine-Driven Alternators," by W. I. Slichter; "Heat Resistance the Reciprocal of Heat Conductivity," by Mr. Wm. Kent; "A Forty-four-foot Pit Lathe," by Mr. J. M. Barnay; "Finer Screw Threads," by Mr. Charles T. Porter; "A Surveying Instrument in the Machine Shop," by Mr. C. C. Tyler; "Gift Propositions for Paying Workmen," by Mr. Frank Richards; "Deflections of Beams by Graphics," by Mr. W. Trinks, and "Topical Discussion on Smoke Consumption."

The participants in debate on these various subjects were Messrs. Suplee, C. V. Kerr, H. E. Longwell, Fred J. Miller, Henshaw, Pomeroy, Henning, Christie, Oberlin Smith, Geo. L. Fowler, E. S. Boyer, Sanguinetti, W. S. Rogers, H. L. Gantt, McGill, Alden, E. D. Meier, Sangster, Ennis, Norris, A. Bement, and E. P. Bates.

Concluding Session. Friday Morning, December 5th.

The final session was called to order by Past-President Charles Wallace Hunt, at 10.15, with a view to securing all time possible for the reading and discussion of papers, although the formal session had been set for half-past ten. The session was convened in the auditorium of the Society House. Vice-President Waitt took the Chair promptly at the hour set for opening.

The first paper was by Mr. J. T. Wilkin, on "Rotary Pumps," which was discussed by Messrs. Tompkins, Lane, Suplee, Kingsbury, Henning, McBride, and Winship. The paper by Mr. H. M. Lane on a "Filing System for Office Use" was discussed by Messrs. Fowler, Crosby, W. E. Partridge, Suplee, Pomeroy and Spangler. The paper by Mr. A. F. Nagle, entitled "Analysis of the Commercial Value of a Water Power per Horse Power per Annum" was discussed by Messrs. Kent, Rockwood, Spangler, Allen, and Lewis. The paper by Mr. Bartholomew Viola on "Centrifugal Machines" was illustrated by models in actual operation and questions were asked by Messrs. Kruesi and Kent, and the concluding paper in the regular series was that of Prof. Albert Kingsbury, on "An Oil Testing Machine and Some of its Results," which was discussed by Dr. R. H. Thurston, Professor Kingsbury and Mr. Kent.

The Topical Discussions, which had not been reached at the session on Wednesday morning, were then taken up and covered a treatment of Elastic Resistance which is offered by bodies to the displacement of particles, resulting in a change of volume, which was discussed by Messrs. Henning, Hale, Suplee, Richards and Kingsbury.

The subject of Oil Burners was discussed by Messrs. Arnold, Williston, Kent, Wilkin, Hand, Suplee, Platt and Kingsbury; Messrs. Lewis, Christie, Bates, LaForge, Kent and Rogers presented discussion on the subject of Separation of Oil from Steam. On the subject of Oil Tempering of Steel, Messrs. E. R. Markham, Oberlin Smith, Rogers, Gabriel, and Williston took part.

By an oversight, matter which had been contributed on the Casting of Iron Around Wrought Iron or Steel Shafts was passed by and deferred to a later meeting.

The Chairman then asked at the close of the professional business whether there were any matters of executive or new business which members would like to present before the motion to adjourn was in order. Mr. E. M. Hewlett, of Schenectady, expressed the pleasure of the members resident in the neighborhood of Saratoga that the Council had given favorable consideration to the proposition to meet at Saratoga, and on behalf of the interest he supplemented the invitations which had already been received.

The Secretary requested that authority might be given to him to return to the Metropolitan Street Railway Company and to the companies operating the big power stations which the members had visited on Thursday, the proper votes of thanks in the name of the Society. He also gave notice of the intention to resume the practice of holding monthly reunions, probably on the first Tuesday evening of the winter months, pursuant to earlier announcement.

On motion, the Secretary was directed to return the thanks of the Society to those corporations and individuals whose guests the Society had been during the continuance of this annual meeting.

The Chairman.—Is there any further new business to come before the meeting?

Mr. Kent.—In a conversation with a few members on the subject of the discussion that was had on the Metric System the other day, it was agreed that it had been left in a very unsatisfactory shape. I therefore have this motion to make:

Moved, that the Council is hereby requested to obtain, by means of a letter ballot, the sentiment of the members of the Society in regard to the bill now before Congress making the Metric System of Weights and Measures the legal standard in the United States.

Second, that such ballot shall contain a reprint of the proposed law and two questions to be voted on, "yes" or "no":

(1) Do you approve of the first paragraph of the proposed Law?

(2) Do you approve of the second paragraph?

It shall also request that the member voting shall express briefly his princpal reasons for or against the Metric System in a statement not exceeding fifty words in length.

In addition to the member's signature to the ballot he shall state his title, position or occupation, and state whether the substitution of the Metric for the English System would have any effect on his business.

The Chairman.—The Chair would have to state in connection with this motion that it would seem to be out of order at this present time. At the larger session of the Society yesterday morning the matter was brought up, but after having spent a good part of the day on the discussion of the pros and cons, the Committee on the Metric System suggested certain resolutions expressing a definite statement of the sentiment of the Society. It was voted by the membership at that time, by laying the resolution on the table, that they did not want to express themselves definitely in regard to it at this meeting, and it would seem it would not be proper to bring the question up at this meeting when a majority of the members decided that they did not want to take it up.

Mr. Kent.—I think that was entirely a different question. It has been decided for the last 15 or 20 years that this Society will not as a Society state that it has an opinion, but it is an entirely different matter to request the members of the Society individually to express their opinions under their names. It has no relation to the vote to lay on the table the question brought up yesterday.

Mr. C. W. Hunt.—I trust that this will not be acted upon at this late hour and at the last session of the annual meeting. This is a matter to affect a proposed law now before Congress. If we enter into the field of influencing legislation in this case a call can reasonably be made for similar action on any other bill that may hereafter come before Congress. Influencing legislation is, in my view, entirely foreign to the objects of this Society, which should be a scientific body, a body to hear and record papers and discussions and make investigations and reports on engineering subjects. What may or may not be done by Congress is a foreign matter. It may concern a commercial society, but does not concern a scientific association; and I think that we should, as a body, keep ourselves entirely free from commercialism. Any of our members who wish to join together to further or hinder the passage of the Law are free to do so, but as a society we should keep entirely free from all trade-union and commercial tendencies which may be quite proper in other associations.

Mr. Kent.—I would say as to the policy of the Society, at the very first session the Society ever had this was considered a proper question to take up. Every scientific society in the nation, I believe, has discussed the question. Engineering societies all over the country and all over the world have discussed it, and if this Society says it will not discuss such a question we will stand unique in the history of the world.

Mr. Hunt.—I object to his calling it a scientific question. It is not. There never was any science in it, and I have got gray-headed reading and hearing this assertion.

The Chairman.—I have not heard the gentleman's motion seconded.

A Member.—I second it.

The Chairman.—It would seem rather a reflection on the Committee who have made the report at this meeting if a resolution of this kind is passed. They have been asked to take the matter up, and their report has been received and ordered to be printed, and the resolutions that were offered by them have been laid on the table, and if it should be placed in the hands of the Council to go ahead, it would seem like a reflection that the Committee had not been competent to carry out their work. Although the motion has been made and seconded, and, if it is desired, I will put the motion, yet I would call attention to the fact that I hardly think the Society, or the member who made the motion, would want to reflect on the Committee.

Mr. Fred J. Miller.—The Committee's resolutions regarding the proposed bill, if they had been passed, would have constituted a radical departure from the position taken by this Society from the start. The Society has always decided that it would not go into such a question or take a position on either side. I would have opposed a resolution endorsing the bill before Congress, because I do not think the Society should place itself on record one way or the other by such a resolution. I think when we have had time to think it over we will all be glad that we tabled those resolutions committing this Society to an entirely different course from that which it has heretofore pursued regarding such matters.

Mr. Halsey.—Engineering and scientific societies all over the country are voting upon this matter, and it seems a very strange state of things if, because of an old tradition, the American Society of Mechanical Engineers, which has more at stake than any other three societies combined, is unable to learn the opinion of its members.

Mr. Hunt.—I think this is an entirely unsuitable time to call up a question of this importance. It seems to me to be both unjust and unsatisfactory, and it proceeds on the assumption that the Society is justified in doing this sort of thing. In my opinion it is a matter foreign to the Society and its purposes.

Mr. Henning.—I seconded the motion yesterday to lay the report of the Society's Committee on the Metric System on the table, on the ground that the passage of such resolution would be absolutely contrary to those principles on which the Society has been conducted for over sixteen years. The whole matter of the attitude of the Society towards the Metric System has been put, by resolution passed at that same meeting, into the hands of the Council, in order that it may take competent and proper action in conformity with the principles of this Society, and, if possible, may gather an expression of opinion from all engineers and not from one group of them. I think for these reasons we should not try at this time to force something through the general meeting in a manner which savors of practical politics, when our Council has been directed to take definite action along other lines. We do not know what the true facts in the case are, and I am surprised at the last moment of a meeting that an attempt to take the matter up in another form, with different members present, after a resolution having somewhat the same purport has been ordered to lie on the table.

Mr. Fred J. Miller.—I do not see that this is the same thing. The resolution adopted yesterday providing for the appointment of members of this Society to confer with members of the other societies and then to express an opinion regarding the merits of the law or regarding the merits of the Metric System, is an entirely different thing from a proposal to obtain the opinions of members of this Society as individuals regarding the law now before Congress, or the Metric System, for that matter. The two things are entirely different. I do not wish to be understood as endorsing the enforced introduction of the Metric System simply because I do not want the Soceity to oppose this proposed law. I think the two things should be kept entirely distinct, but believe there is a sentiment among a good many members of the Society to the effect that the mechanical engineers of the country are almost infinitely more interested in standards of length and of measurement than is any other body of engineers. I believe that is true. For that reason it would be perhaps desirable that this Society should take action of its own, independent of the other engineering societies, and for that reason I can see no objection to an effort being made to call out an expression of opinion by the members of this Society on this question in the same way that has been done by the Franklin Institute I believe, and by the Western Society of Engineers I am certain, and for that reason I should not oppose this resolution if the Chair declares it in order, which I believe has not yet been done. But if such a resolution is adopted, I should propose an amendment that, inasmuch as the paper of Mr. Halsey and the discussion upon it will have to be put in type by the Society at any rate, probably little additional expense would be incurred if the paper and all the discussion complete were sent to each member with the request that he carefully read it and then cast his vote. I think that Mr. Christie's paper, carefully read by the members of this Society, ought to have considerable effect.

I am sorry it was not more generally heard; it was a good, sound paper. It ought to be read before deciding that question. So that if the resolution of Mr. Kent is in order and is to be voted on, I propose an amendment to that effect.

The Chairman.—I would state for the members that the motion as it has been made would seem to be in order.

Mr. Kent.—I have no objection to accepting that amendment. What I propose is, no expression whatever by the Society as a society, but simply to use the clerical machinery of the Society in order to collect together the opinions of the men with their own signatures.

The Chairman.—What would be done with the discussion?

Mr. Kent.—The whole matter would come before the Publication Committee, to publish the resolutions in such form as they think best.

The Chairman.—Might I ask Mr. Kent just what relation this work would have as regards the work laid out for the special committee appointed yesterday to take up the subject, not only for this Society, but in a broader way?

Mr. Kent.—It would have no relation whatever. That other committee could do the work assigned to it. This is merely a collection of individual opinions of men to write over their signatures what they think on the subject.

Mr. F. A. Halsey.—The vote of yesterday was in accordance with the same tradition that led to the action taken at the Boston meeting last spring, and yesterday's action will, I believe, be misunderstood at Washington precisely as the Boston action was misunderstood. I have no doubt that yesterday's vote will be understood at Washington to mean that the Metric advocates have been able to prevent a vote being taken, and I believe that what we have done up to the present time will assist the passage of the measure.

Mr. Fred J. Miller.—This Society cannot avoid being misunderstood. The action taken at Boston was misunderstood, I think, but we always have our records. If anybody wants to find out the action of the Society regarding anything of this kind he can consult the records; but if he will not do that, we cannot prevent his misunderstanding. Anybody is likely to be misunderstood by persons who do not take pains to investigate.

At the close of the debate the Chair put the question on Mr. Kent's resolution, and in that form the motion was carried.

The motion to adjourn being in order, Vice-President Waitt expressed regret that business engagements had prevented the presence, at the closing session of the convention, of President-elect James M. Dodge, that he might turn over to him the gavel, which is the emblem of authority. He expressed also his thanks to the Society for their courtesy and co-operation in the work of the Chairman, and on motion the convention adjourned.

The evening of Wednesday, which has usually been left open for the convenience of members attending to personal business, was devoted to the discussion of the Metric System. The afternoon of Thursday was devoted to a visit to the power stations of the Interurban Street Railway Company at Ninety-third Street, the Manhattan Elevated Railway at Seventy-fourth Street, and the waterside station of the New York Edison Company at Thirty-eighth Street. The Interurban Street Railway Company arranged that the Metropolitan Street Railway Company should furnish free transportation by ticket for these visits. The opportunity to study and examine, under competent guides, these late examples of large unit practice in power generation was much appreciated.

On the evening of Thursday the usual reception of the annual meeting was held at Sherry's, Forty-fourth Street and Fifth Avenue. The members were received by Vice-President Waitt and by President-elect James M. Dodge and Mrs. Dodge; 606 members and guests were present.

On the afternoon of Friday, by the courtesy of Mr. C. B. Rearick, of the D'Olier Engineering Company, an excursion was organized to the works of the De Laval Steam Turbine Company at Trenton.

No. 955.*

APPARATUS FOR OBTAINING A CONTINUOUS RECORD OF THE POSITION OF AN ENGINE GOVERNOR AND THE SPEED OF THE ENGINE WHICH IT IS GOVERNING.

BY JOSEPH C. RILEY, BOSTON, MASS.

(Non-Member.)

From the earliest days, when automatic devices were first used to regulate the speed of steam engines, attempts have been made to discuss mathematically the motions of the regulators or governors. Watt's original pendulum governor, turning steadily on its vertical spindle with but little work to do, offered slight difficulty; but the almost innumerable forms developed since then have so complicated the task that equations dealing with all the forces which influence a governor's motion must usually contain factors not only uncertain, but quite unknown. Terms must be introduced to allow for that indefinite quantity, friction, as well as external resistance and inertia of parts actuated by the governor; and the result is a set of equations useful for little more than a mathematical study until the unknown coefficients can be determined by experiment.

Of the many excellent steam-engine governors in use, very few were developed by mathematical investigation. Nearly all are the result of repeated trials and continual improvements of types already existing. But although they are remarkably successful in regulating both closely and quickly, it is none the less true that their operation and proper adjustment are not generally understood. This statement applies particularly to shaft governors which revolve in a vertical plane, and which usually actuate one or more valves; for such governors are not only influenced by more forces than ordinary conical pendulum governors, but generally they run at high speed in a position which makes it difficult to study them. A complete account of the behavior of such a governor while actually regulating its engine has never yet been

* Presented at the New York meeting (December, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

given. That it would be interesting, to say the least, has often been admitted; and yet the number of experiments which have been made to find out what any governor *actually does* when governing is far less than the number of equations which have been written to show what it *would do* if subjected to only those influences which can, without much difficulty, be discussed in figures.

To obtain information of the relations between speed and position and the influence of friction in governors, a number of experiments were made by W. G Hibbins, under the direction of Prof. R. H. Smith, at Mason College, Birmingham, England. Nine different governors were used; six of them of the ordinary throttling type, revolving on vertical spindles, and controlling throttle valves ranging from 1¼ to 3½ inches in diameter. For testing, each was mounted on a special stand with its valve, and could be driven at any desired speed by means of a belt. A pencil, clamped to the governor sleeve, marked on a rotating drum and recorded continuously the height of the sleeve. From mean ordinates of the diagrams obtained for each different speed of an increasing and a decreasing series, a speed-position plot was made, and the difference in position for any given speed, when rising and again when falling, was clearly shown. Tests were made on two shaft governors arranged to rotate between lathe centres, while observations were taken of the position of the control point and the speed of rotation. One of them, a Turner-Hartnell governor, carried an eccentric, the position of which when running was determined by moving a pointer, carried on the lathe slide-rest, until it was just touched by the eccentric as it revolved. After first obtaining the position for each speed without the eccentric-strap, the strap was then put on, and an attempt made to approximate the valve resistance under working conditions by means of a spring attached to the eccentric-strap and a wire guide to keep the strap from turning. This method of loading the governor is so far from a correct representation of the actual conditions when running, that it is difficult to see how the results can be of practical value. In the other shaft governer tested by Mr. Hibbins, the centrifugal force of two weights on right-angled bell-crank levers moved a sleeve lengthwise along the shaft and operated a throttle valve. The sleeve position was read by direct observation against a scale.

Experiments similar to this last have been made by students at the Massachusetts Institute of Technology, on a Buckeye, No.

2, shaft governor mounted especially for experimental work, and driven by a belt and cone-pulleys. To the eccentric controlled by this governor, a circular disc was fastened, so that it turned about the shaft as the governor weights changed their position. The relative motion of this disc was transmitted through two steel tapes to a block sliding in a slot in line with the shaft. This device could be used both as an index of the governor's position and as a means of weighing the "force-power" exerted by the governor when the speed was increased and the weights restrained from moving outward.

It will be noted that in these experiments the governors were tested on special pivots, not in place on their engines. If a governor is to be tested for "geometric sensitiveness" influenced only by internal friction, then it is advisable to disconnect from the engine and drive it from some external source. In such a case, provided that positions are to be observed only when running at constant speed, a simple form of measuring or recording apparatus can be arranged for almost any governor. If, however, the effect of valve resistance, external friction, and sudden change in load are to be investigated, if the time necessary for regulation under working conditions is to be measured for comparison with values obtained by mathematical calculations, then it is necessary to test the governor in its place on the engine. The results of such a test show what the governor is doing when actually at its work as a regulator, and are, it is claimed, of greater value to a designer than any tests where artificial means are used to imitate working conditons. When tests are conducted in this manner, simple apparatus for recording or even for measuring governor position can seldom be applied. Shaft governors are usually placed inside the rim of the fly-wheel, often close beside a bearing, a protected position rendering unnecessary any other guard around the revolving weights, but a position which, when the engine is in motion, makes the governor about as inaccessible for experimental purposes as can readily be imagined. Any mechanical device to connect one of the governor's moving parts with an index traveling over a fixed scale in a position more favorable for observation would be difficult to arrange; and even though it were very lightly made, it would impede free action of the governor gear by the effect of centrifugal force and inertia of its parts. Accordingly, in the following experiments, it will be noticed that although the motion of the governor was to be investigated, the governor itself was evidently considered quite inaccessible, and measurements were taken of the motion of the valve-rod, a part controlled by the governor, yet in a much more accessible position.

In 1893, Mr. Walter Ferris made some tests on the governor of a New York Safety automatic engine at Lehigh University. This governor was of the shaft type, and moved an eccentric inward and forward as the speed increased. A pencil, held in a clamp on the valve-rod, was arranged to mark on a sheet of paper moved by clockwork in a direction at right angles to the rod. A zigzag line was thus drawn from which the length of valve travel during any particular revolution of the engine could be measured. Much more elaborate apparatus for recording variation in valve travel has been used by students at the University of Illinois. The paper on which the record was taken was in the form of a long ribbon drawn between rolls across the line of motion of a recording pencil clamped to a pantograph, which enlarged the motion of the valve-rod. Records were taken from an Ideal engine, 10 x 10 inches, at about 310 revolutions per minute. By opening or closing the circuit of a generator driven by this engine, the load could be instantly varied from 6 to 50 horse-power. This was certainly a severe test of the governor's good quality; but the diagrams showed that somewhere in the vicinity of 4 revolutions were all that were necessary before the governor had done its work and settled down in its new position, decreasing the valve travel from $2\frac{1}{4}$ to $1\frac{3}{4}$ inches. Records were also taken to show the hunting action of the governor when adjusted to approximate isochronism. An improvement in the apparatus was afterwards made by adding a second pencil fastened to the armature of an electro-magnet, and arranged to make marks at intervals of one second. Good records were obtained with this apparatus, but the information they gave was very incomplete They showed merely that at the moment when the eccentric passed one of its dead-points, its distance from the centre of the shaft was a certain amount. What this distance was at any other time could not be told. A varying distance between points across the zigzag line indicated nothing, except that during a certain time (not necessarily one-half a revolution, on account of variation in angular advance of the eccentric), the eccentric had changed its position. The exact time of the change was unknown. To be sure, the time required for one-half a revolution at 310 revolutions per minute is not very long; but it will be shown later that even in so brief an interval the governor of a much larger engine than this can perform motions both interesting and important.

Professor Jacobus once obtained records of the distance between eccentric and shaft of a 50-horse-power Ball and Wood engine. He attached a pencil directly to the eccentric, and made it draw a spiral diagram, the locus of the centre of the eccentric as it revolved about the shaft at varying radius. Though no record of time was produced, approximate time intervals in terms of one revolution could easily be obtained from angles measured at the centre of the diagram. This device served to compare the action of the governor when running with and without a dashpot to dampen its oscillations. However, the records which could be taken were necessarily of brief duration, limited, in fact, to four or five revolutions; in a longer time, the line drawn would cross and recross itself and become indistinguishable. A device of this sort would not be generally applicable for experimental work. It could hardly be used at all, unless the eccentric were in an exceptionally accessible position, near the end of the shaft, and probably outside the fly-wheel.

None of these devices can furnish data sufficiently precise or complete to adapt the theoretical equations to practical use in designing. A device satisfactory for experimental use should show the position of the governor and the time required for any given change in position, or, what is more interesting in the study of inertia governors, the rate of change in velocity during that change in position. It should show not only the distance from centre of eccentric to centre of shaft, but also the relative angular position of the eccentric with respect to the crank and of the crank with respect to the line of dead-points. It should be applicable, in one form or another, to any engine, yet of such a nature that it will not impede free motion of the gear or alter it in any way. Since changes in governor position take place so quickly, the apparatus should produce a permanent record of both position and time; and the time intervals should be marked in such a way that they may be made as short as desired.

The apparatus now to be described fulfils, in a measure, nearly all these requirements. It produces on a strip of paper, in parallel lines, so that they may be compared, an almost continuous record of the position of any part of the governor; a record of time intervals of any duration even to a small fraction of a second; a record of the angular position of the crank, as many times in one revolution as may be desired; and an automatic record of change in load on the engine, or any other event. The records are made by electrolytic decomposition of a chemical salt absorbed by the paper which is drawn under a series of recording styles while it is still damp. The solution used in this work was yellow prussiate of potash and ammonium nitrate in water. The passage of even a very weak current of the briefest imaginable duration, from the recording style (a piece of steel wire) through the paper, produces a clearly defined mark of Prussian blue. Chemical action takes place only while the current is passing, so that if the electrical circuit through any one of the styles is continually made and broken, the record produced is a series of sort dashes separated by spaces whose length depends upon the speed of the paper. Time intervals are recorded by momentary closure of the circuit through one style by a seconds pendulum swinging through a globule of mercury; briefer intervals, by rapidly interrupting the current through another style by means of an electrically driven tuning-fork. Provided the time intervals are short enough, uniform motion of the paper is not essential.

The apparatus can best be described and the method of recording governor position made clear by explaining it as used in connection with an engine from which records are to be shown.

The engine is a McIntosh and Seymour tandem compound, 11 and 19 by 15 inches, in the Engineering Laboratory of the Massachusetts Institute of Technology. The governor, shown in Figs. 1 and 2 has two weights, pivoted at *B*, which by swinging outward, away from the shaft, cause the "pendulum," shown by heavy lines in Fig. 2, to swing upward about its pivot, *C*. A curved slot in the pendulum surrounds the shaft. Fastened to the pendulum is an eccentric which actuates a piston valve for the high-pressure cylinder. Outward motion of the governor weights causes inward motion of the pendulum, so called because it carries the eccentric inward toward the shaft. Pivot *C* is so placed with reference to the crank that inward motion of the pendulum, in response to increased speed, increases the angular advance of the eccentric besides decreasing its throw. The angular motion of the pendulum between extreme positions is 7.3 degrees. A horseshoe-shaped spring acts through two adjustable rods to force the governor weights inward.

FIG. 1.

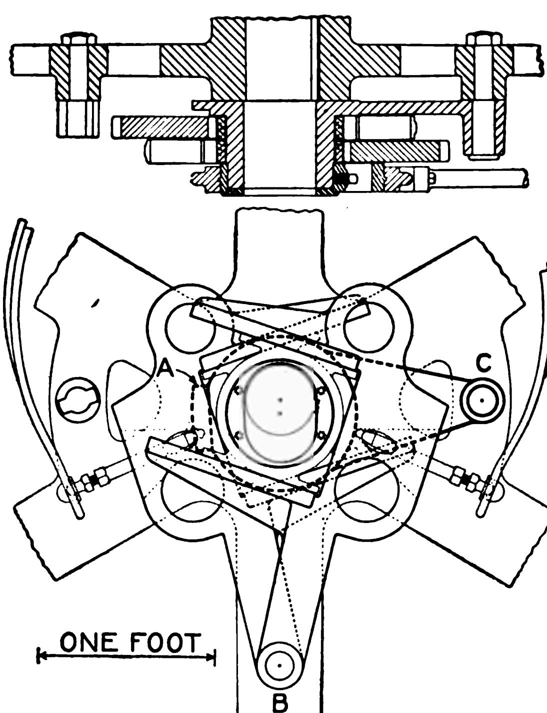


FIG. 2.

The "position-point," Fig. 3, was fastened to the pendulum at A, Fig. 2, so that it swung about *C*, in an arc of 23.41 inches radius. Its extreme end is just visible in Fig. 1. Its angular distance from its initial position is to be shown by the record.

Fig. 4 shows Position-block No. 1, the first one used. It consisted of 26 thin strips of brass and two thicker ones insulated by

FIG. 3.

strips of hard rubber, bolted firmly together and finished smoothly on top. This block, on its wooden support, was securely fastened

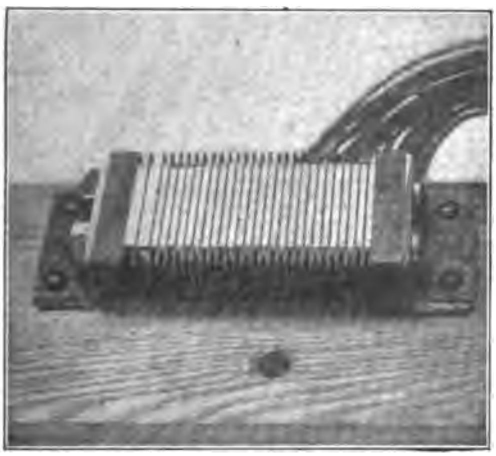


FIG. 4.

to the fly-wheel in such a place that the position-point traversed its face with very slight friction. The strips were numbered from 4 to 31, 4 being nearest the outer position of the position-point, and 31, one of the two wide strips, being at the extreme inner position. The greatest possible motion of the position-point was about $\frac{1}{8}$ inch more than the width over all the strips. A wire was soldered to each strip, and the cable formed from these was led along an arm of the fly-wheel to a device at the end of the shaft, which, for want of a better name, will be called the "commutator."

This had 30 brass rings insulated by rubber washers of slightly larger diameter and numbered from 1 to 30, beginning next the wheel. To the inside of ring 4 was fastened the wire from strip 4, and so on to 30. The wire from strip 31, not having a ring of its own, was connected to ring 4. From ring 3, a wire led back along the cable to a point where it was spliced to a light, flexible cord leading to the position-point. A current to the commutator at ring 3 would pass in along this wire, through the position-point, to

FIG. 5.

whatever strip the point might be touching, and back to the corresponding ring on the commutator, from which it was taken off by the brush seen in Figs. 5 and 6 and sent to its proper style over the recording roll. Ring 2 was not used. The current to ring 1 went to the contact points on the counter disc at one end of the commutator and was taken off by a special brush, seen in Fig. 6, and sent to the counter style.

There were ten of these contact points, equally spaced. One of them, somewhat longer than the rest, made contact with the brush just as the engine passed its head-end dead-point.

The paper, having been soaked in its solution and then partially dried, was wound on a wooden roll at the left of the roll-frame, Fig. 6; from here it passed up between a steel roll and the recording styles, and thence through a pair of feed rolls driven by a motor. Current for the motor came through the lower plug and cord; current for all the records through the upper plug and cord, the negative wire returning from the roll frame and the positive leading through suitable lamp resistance to the various circuits. Each style was a piece of wire rounded at the point, forced through

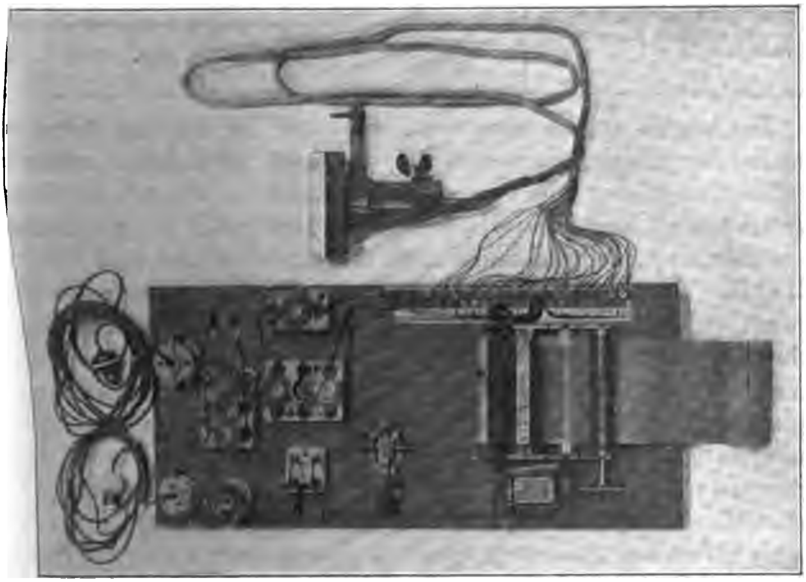


FIG. 6.

a hole in a block of wood, carefully aligned and connected to its proper circuit. Style 1, farthest from the motor, was in the circuit of a seconds pendulum, already mentioned; No. 2 was the counter style and made one long and nine short dashes each revolution. Records of short intervals of time will be mentioned later. Style 3, the signal style, was used to record the instant of changing the engine load. Its circuit could be closed by a telegraph key or automatically by a wiping contact on the handle of a clutch overhead on the main shaft. The latter was used for all records.

The engine was loaded by a friction brake and a rotary pump driven through the clutch just mentioned. By snapping out the clutch, the engine was relieved of the pump load.

A specimen record showing the behavior of the governor and speed of the engine during a sudden change in load is shown in Fig. 7. For certain reasons this particular record seemed well suited for illustration, although the governor was not adjusted to regulate very closely. The following table will serve to interpret the record:

Number of position strip and position record.		10	13	16	19	22
Displacement in degrees of governor pendulum from extreme outside position, i.e., position when at rest.	Outside edge of strip.	1.72	2.43	3.14	3.86	4.57
	Inside edge of strip.	1.87	2.58	3.31	4.04	4.75

The engine speeds have been computed by taking from the record the number of revolutions and tenths, with hundredths by estimation, during one second before and one second after any given second, and multiplying by 30. The result in revolutions per minute is recorded underneath the given second and marked R.P.M. An even number of seconds must be chosen for the count, so that the time interval may be from one instant when the pendulum makes contact until it makes contact again, swinging in the same direction. This prevents any error due to a large globule of mercury. The record shows that with the engine running at a speed of 228 revolutions per minute, the clutch was snapped out about 5.62 seconds after the recording apparatus was started. Cards taken simultaneously on four indicators, immediately before and again soon after this change, show a decrease from 145 to 82 indicated horse-power. At that moment the engine, on its return stroke, had not quite reached its head-end dead-point. The position-point carried by the governor pendulum was moving on and off strip number 10, about 1.8 degrees from its extreme outer position. As this is not an inertia governor, considerable change in speed is necessary to start the governor weights outward, yet after a little more than one revolution, they started, the position point crossing strip 11, moving nearly across 12, then back a little, then crossing 12 to 13, registering as it went, moving back, then crossing 13, 14, and 15, oscillating in and out on the way, but still progressing inward, never in contact with two strips at once, but touching one almost as soon as it left another, until it first touched strip 21, its mean position after the change in load, about 8.57 seconds from the time of starting the record. In about 2.95 seconds, due to a sudden drop of 63 horse-power, the speed had

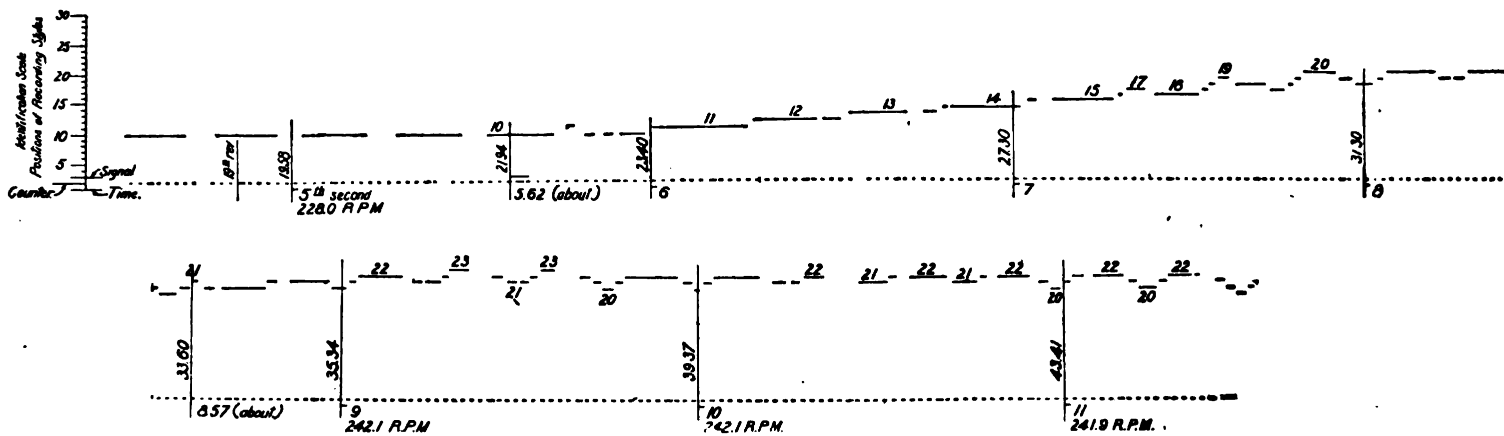


Fig. 7.—Portion of Record Taken During Change in Load.

Read from left to right. The lowest line of numbered dashes shows the time in seconds from beginning of record. Ten dashes on the counter-line indicate one revolution of the engine, the left-hand end of each long dash marking the head-end dead-point. A dash on the signal-line, between the 5th and 6th seconds, marks the instant of a sudden change in load from 145. to 82 horse-power. Records on lines 4 to 30 indicate contact of governor position-point with position-strips of same number. Upward progression of position record indicates outward motion of governor weights due to increased speed. This record was taken with position-block No. 1.

increased from 228.0 to 242.1 revolutions per minute, and the governor pendulum had shifted its position about 2.6 degrees. One record is lacking to complete the information—namely, a record of short intervals of time. The counter record, however, by allowing for change in speed, makes a fair substitute.

This record was continued to the eighteenth second; after the thirteenth, the speed decreased to 241.7 revolutions per minute, and then did not change appreciably; yet though the speed was constant, the position-point did not settle on any single position strip. The record shows an oscillation occurring once in each revolution of the engine, thus revealing the fact that the governor was never in a state of relative rest. This certainly is not surprising. The governor was doing work in pushing and pulling a valve back and forth very rapidly, and its equilibrium was somewhat disturbed. Besides, since it revolved in a vertical plane, during one-half of a revolution it was assisted and during the other half opposed in its motion by the action of gravity. The separate influences of valve resistance and gravity on the revolving weights remain to be shown. This motion is of great importance. If a governor is *always* in motion with respect to its own pivots, then there is no statical friction to be overcome, before it can change its position, and sticking in one position during a change in speed cannot occur.

To investigate this cyclical change more minutely, Position-block No. 2 was made. It had 52 strips of brass so close together that they covered the same range of motion as only 13 strips of block 1. The strips were numbered from 5 to 56. Recording style 4 was reserved for a time record, so but 26 styles were available for position records. Accordingly the strips were connected in two series, so that 5 and 31 registered through style 5, 6 and 32 through style 6, and so on. A little experience in interpreting the record prevented any confusion arising from this duplicate system.

An electrically driven tuning-fork, carrying an adjustable weight, was arranged to interrupt the circuit through style number 4, and thus record very short intervals of time. By aid of this record to check the record of seconds by the pendulum, it was proved that the centres of dashes at one second intervals could be accurately located. Thus it became no longer necessary to use an even instead of an odd number of seconds in computing speeds.

Records shown in Figs. 8 and 9 were taken to study the effect of increasing the inertia of the reciprocating parts driven by the eccentric. Fig. 8 represents nearly the conditions existing after the change in load of Fig. 7. Although no indicator cards were taken, it is known that the load was about 80 horse-power. The engine was making about one less revolution per minute, and

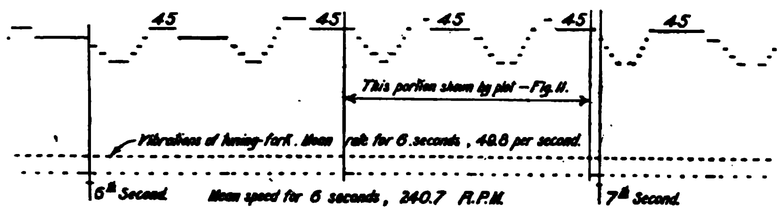


FIG. 8.

Portion of a record taken while a constant load was on the engine. The record was taken with position-block No. 2.

consequently the pendulum was a little nearer its initial position. Block No. 2, with its very narrow position-strips, of course shows the pendulum oscillation to better advantage than block 1.

Before taking Fig. 9, a split cylindrical weight of 25 pounds (the valve and valve-rod together weigh 43 pounds) was clamped firmly around the valve-rod. An attempt was then made to duplicate

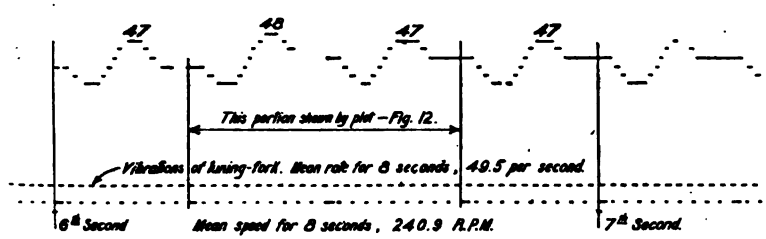


FIG. 9.

Portion of a record taken under same conditions as Fig. 8, except that a weight of 25 pounds was fastened to the valve-rod.

the conditions of Fig. 8. From the style records, it appears that in one case the mean position of the position-point, as it oscillated, was between strips 43 and 44; in the other case between 44 and 45; but the angular difference is less than one-tenth of one degree, so that it is proper to compare the two oscillations. Representative oscillations from these two records are plotted in Figs. 11 and 12, with crank angles and time as abscissae, and angular displacement of the governor pendulum from its position when at rest as ordinates. The precision of this method of recording is shown by the regularity with which the plotted points fall into line. Provided the displacement scale is correct, the time necessary for a given change in position can be read within one one-hundredth of a second. For the closer measurement of time, which may be desirable in studying accelerations of inertia gov-

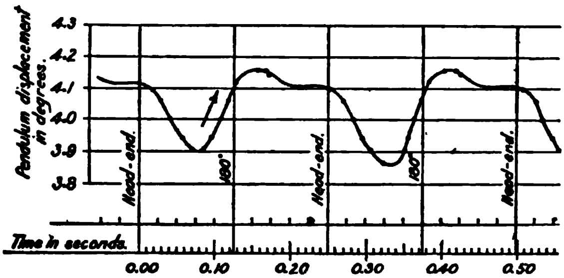


FIG. 11.

Plot to accompany Fig. 8, showing motion of governor pendulum under normal conditions. Speed, 240.7 revolutions per minute.

ernors, it will be necessary only to draw the paper faster under the recording styles and perhaps make the tuning-fork vibrate faster. Portions of these plots between crank angles 270 degrees and the head-end dead-points, appear to be indefinitely located. From other oscillations of the same records, however,

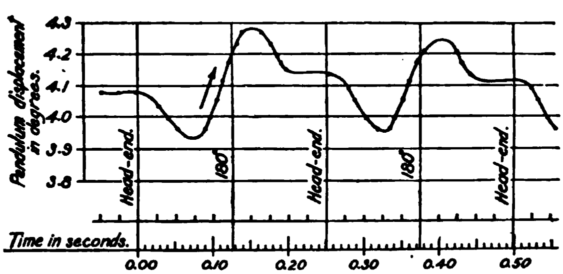


FIG. 12.

Plot to accompany Fig. 9, showing motion of governor pendulum when valve inertia is increased. Speed, 240.9 revolutions per minute.

these portions were found to rise very slightly till near the dead-point.

To make clear what is to follow, let it be again stated that *inward* motion of the pendulum is motion away from that position which it occupies when the engine is at rest. During such a motion the pendulum displacement angle increases.

An explanation of the oscillations demands an understanding of the relative positions of pendulum, shaft, eccentric, and crank. Fig. 13 shows the crank about 30 degrees beyond its head-end dead-point. Gravity acting on the heavy left-hand end of the pendulum, on the eccentric it carries, and also on the eccentric-strap, has for some time been tending to pull it *outward*, or downward about pivot *C*, Fig. 2. About this time, the valve is beginning to move toward the shaft; and its inertia, its resistance to acceleration, reacts on the eccentric to pull the pendulum *outward*. Thus gravity and valve inertia are acting together, and the curves of pendulum displacement slope quickly downward. At about 90 degrees, Fig. 14, the pendulum hangs nearly vertical, and gravity scarcely influences it. Valve inertia acts slightly for a little longer; yet the pendulum continues *outward*, due to its own inertia, until after the actuating forces have reversed their direction. As the crank moves on toward 180 degrees, gravity tends to pull the pendulum *inward;* inertia of the valve, which is being retarded, tends to assist, and the plots rise very quickly. When the crank gets to about 220 degrees, Fig. 15, the pendulum is once more approaching a vertical position and supporting its weight on pivot *C;* but just then the valve must be accelerated toward the right, away from the shaft, and reaction along the eccentric-rod pushes the pendulum back, moving it *outward*. This action is very much more energetic in Fig. 12 than in Fig. 11, due to the increased inertia of a weight nearly two-thirds as large again. Finally the crank reaches about 270 degrees. The pendulum stands nearly vertical and the eccentric is close to that position in which it neither accelerates nor retards the valve. Consequently the pendulum pauses in its oscillation. From there on, as the engine turns, gravity tends to turn the pendulum *outward* ; but inertia of the valve, retarded in its motion, acts in an opposite sense; and these two influences, both increasing rapidly, appear to increase about equally, so that the pendulum, acted upon by balanced forces, scarcely moves until the head-end dead-point is passed and the revolution is completed.

Contrary to expectation, when the valve inertia was increased, the amplitude of oscillation was hardly any greater than when the governor was running under normal conditions. Apparently these cyclical oscillations are due not so much to inertia of the valve as to rotation of the unbalanced pendulum in a vertical plane.

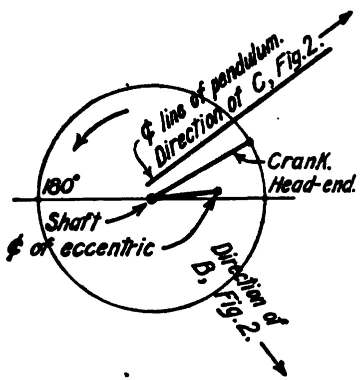


FIG. 13.—CRANK ANGLE.
80 Degrees.

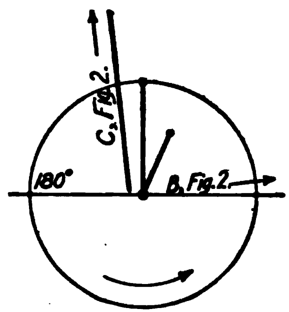


FIG. 14.—CRANK ANGLE.
90 Degrees.

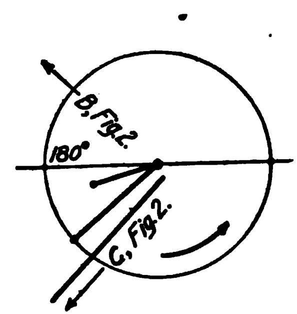


FIG. 15.—CRANK ANGLE.
220 Degrees.

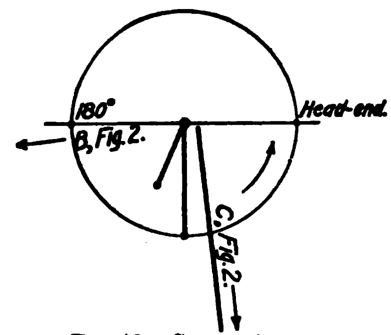


FIG. 16.—CRANK ANGLE.
270 Degrees.

Relative positions of pendulum, shaft, eccentric and crank, with respect to the line of dead-points, for varying crank angles. The engine cylinders are off to the right.

The influence of the two governor weights on this oscillation of the pendulum has not been mentioned. It is slight; for in nearly all positions one weight tends to counteract the other.

Herr Otto Schneider in his "Theorie der Flachregler,"* discusses mathematically the various forces which tend to influence the otherwise simple relation existing between speed, spring tension, and moment of inertia in a fly-wheel governor. He confines the discussion to shaft governors carrying eccentrics, and distinguishes as the disturbing factors:

1. Valve friction, including friction at the stuffing-box.
2. Inertia of the reciprocating parts.
3. Steam pressure on the end of the valve stem.
4. Weight of eccentric and pendulum (of valve and rod also in the case of vertical engines).

He then computes the magnitude of each of these forces and shows graphically how each varies during a revolution of the engine. Then, combining the effects of these forces, he shows a diagram of pendulum oscillation for one complete revolution. His work as published is entirely mathematical; and as the governor for which his calculations were made was probably suppositional, it is doubtful if he had any experimental data to verify the character of the motion he deduced for the pendulum. Yet his deductions bear a close resemblance to the oscillations actually detected and measured in this experimental work. The two must not be too closely compared, for the mechanisms of the governors are quite unlike.

This report is presented merely to describe apparatus for obtaining experimental data of the behavior of engine governors. The apparatus was first applied to the McIntosh and Seymour engine simply to find out whether or not it could be made to work—not to obtain figures for comparsion with any calculated results. The governor of this engine would be a particularly difficult subject for mathematical treatment, on account of its peculiar spring. A spring of irregular curvature exerts a force which is hard to calculate; and a spring made of several leaves, especially when they are curved, does not always exert the same force for the same deflection.

It is proposed to use this apparatus for investigating the action of some form of single-weight inertia governor. After deter-

* *Zeit. des Ver. deu. Ing.*, Oct. 19, 1895, p. 1257.

mining, by a visual stroboscopic method, the approximate position of the weight while running, a position-block may be made to cover only the normal range of motion from lightest to heaviest load. These governors usually have helical springs, easy to calibrate, and the whole design is such that all the forces at work, excepting friction, can be computed analytically. They can be adjusted to regulate very closely and very quickly; but although their motions are quick, the recording current is quicker, and the precise position of the weight with the direction and velocity of its motion at any instant should not be difficult to determine. If reliable data of the actual performance of one of these governors can be obtained, perhaps the information may at last be supplied to make it possible to predict, by analytical investigation, the action of any governor of the same type.

BIBLIOGRAPHY OF EXPERIMENTAL WORK ON ENGINE GOVERNORS.

"Behavior of a Fly-Wheel Governor under Sudden Changes in Load."—Walter Ferris, *American Machinist*, Feb. 13, 1896.

"An Apparatus for Automatically Recording the Action of a Shaft Governor." —Professor L. P. Breckenridge, *American Machinist*, Dec. 5, 1895.

"A Governor Indicator."—A. H. Neureuther, *The Technograph* (University of Illinois annual), 1897–98.

"Experiments upon the Action of Engine Governors."—William George Hibbins, *Proceedings Institution Civil Engineers*, 1899; vol. cxxxvii.

"Experimental Determination of the Quickness of Action of a Shaft Governor." —Professor D. S. Jacobus, *Proceedings American Association Advancement Science*, August, 1893; vol. xlii.

"A Method of Testing Engine Governors."—Herbert Byrom Ransom, *Proceedings Institution Civil Engineers*, 1893; vol. cxiii.

ARTICLES ON THE GENERAL SUBJECT OF MEASUREMENT AND COMPARISON OF THE SPEED OF ROTATING SHAFTS. TO THOSE ARTICLES MARKED WITH ASTERISKS, SPECIAL ATTENTION IS CALLED.

Mechanical counters:

"A Positive Speed Indicator."—Oberlin Smith, *Transactions American Society Mechanical Engineers*, 1883-84; vol. v.

"Spratt's Electrical Speed and Direction Indicator.—*Electrical Review* (London), Oct. 19, 1894.

Mechanical devices for comparing speeds:

*"Amsler's Tachometer."—*La Nature* (Paris), Nov. 17, 1894.

"Duveau's Speed Register."—*Scientific American Supplement*, Nov. 9, 1899.

"Haynes' Kinemeter."—*Railroad Gazette*, Nov. 18, 1887.

*"Epicyclic Gearing for Measuring Differences in Angular Velocity and Position."—A. C. E. Rateau, *Bulletin Société Internationale Électriciens*, Dec. 1901,

Mechanical and electrical recording devices:

"The Moscrop Speed Recorder."—*Catalogue of Ashcroft Manufacturing Co.*, Boston, 1900.

"Horn's High Speed Indicator."—*Die Elektrizität*, April 10 and May 8, 1897. *Catalogue No. 8, Dr. Th. Horn*, Grosszschocher—Leipzig. For specimen records see *Zeitschrift Vereines deutscher Ingenieure*, May 14, 1898.

"Apparatus for Registering Speed Variations."—Paul Boucherot, *Iron and Coal Trades Review*, Oct. 13, 1899.

* "Methods of Testing Engine Governing."—F. W. Roller, *American Electrician*, Dec., 1897.

"An Electric Speed Recorder."—George H. Barrus, *Transactions American Society Mechanical Engineers*, 1887-88; vol. ix.

"An Automatic Printing Speed Counter."—Professor George S. Moler, *Transactions American Institute Electrical Engineers*, May, 1893; vol. x.

* "A New Method of Measuring Variation in Angular Velocity."—Friedrich Klönne, *Elektrotechnische Zeitschrift*, Aug. 4, 1902.

Devices recording time by vibration of tuning-fork:

* "Angular Variation in Steam Engines."—P. O. Keilholz, *Transactions American Institute Electrical Engineers*, Oct. 25, 1901.

* "Experimental Method of Measuring the Regularity of Steam Engines."—L. E. F. David, *Bulletin Société Internationale Électriciens*, Nov., 1901.

* "Ransom's Cyclometer."—*Engineering*, Jan. 1, 1892 and Sept, 28. 1888.

* "The Cyclical Velocity Variations of Steam and Other Engines."—Herbert Byrom Ransom, *Proceedings Institution Civil Engineers*, 1888-89; vol. xcviii.

Stroboscopic devices:

* "Optical Method for Determining the Law of Periodic Variation in Speed of a Rotating Prime Mover."—Professor Alfred Cornu, *Bulletin Société Internationale Électriciens*, Nov., 1901.

* "Study of the Variations in Speed of an Otto Gas Engine by Aid of Stroboscopic Apparatus."—Professor Alfred Cornu, *Bulletin Société Internationale Électriciens*, Jan., 1902.

* "Sartori Stroboscopic Method of Measuring Variation in Angular Velocity."—Professor J. Blondin, *Bulletin Société Internationale Électriciens*, Jan., 1902.

* "A New Apparatus for Measuring the Variation in Speed of a Fly-wheel during One Revolution."—E. W. Mix, *Electrical World and Engineer*, Feb. 8, 1902.

"Instantaneous Variation in Speed by Vibratory Tachometer."—Professor D. S. Jacobus, *Proceedings Institution Civil Engineers*, 1898-99; vol. cxxxvi.

"A Method of Comparing the Speed of any Shaft with that of Another."—G. Behnischke, *Elektrotechnische Zeitschrift*, Feb. 16, 1899. Translation in *Electrical Review* (London), Jan. 5, 1900.

Electrical counters indicating speed by voltage of current generated by small magneto machines:

"Fessenden's New Tachometer."—*Electrical World*, Dec. 5, 1896.

"Electrical Teletachometer."—Professor Édouard Hospitalier, *Bulletin Société Internationale Électriciens*, May, 1902.

"Electro-Dynamic Company's Speed Indicator."—*American Machinist*, Dec. 10, 1896.

No. 956.*

FLYWHEEL CAPACITY FOR ENGINE-DRIVEN ALTERNATORS.†

BY WALTER I. SLICHTER, SCHENECTADY, N. Y.
(Junior Member of the Society.)

1. The following paper is written with the object of showing certain considerations which must be borne in mind when selecting a steam engine to drive an alternating current generator which is to run in multiple with another generator or which is to generate power for a system in which synchronous apparatus, such as synchronous motors or rotary converters, are to operate.

A detailed analysis of the mechanical action in the engine which is the cause of the trouble is to be found in Mr. J. I. Astrom's paper, and the discussion thereon, read before this Society last year at Milwaukee. I have omitted as much of the part that Mr. Astrom discussed as could be done and still give a clear idea of the effects in the electrical circuit.

2. An alternating current generator, when direct-connected to a steam engine, is sensitive to certain irregularities in the speed of the engine which affect no other type of apparatus. This irregularity is in the instantaneous value of the speed, or the variation of the angular velocity during one revolution as distinguished from the changes in the average speed, due to a change of load or of steam pressure.

3. During one revolution the force applied to the crank-pin of a steam engine varies considerably, due to the following causes:

Transfer of reciprocating to rotating motion.

Variation in steam pressure on the piston, due to expansion.

Inertia of the reciprocating parts.

Weights of the reciprocating parts.

---

* Presented at the New York meeting (December, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

† For further references on this subject see *Transactions* as follows:

No. 234, vol. viii., p. 191: "Formulæ for Reciprocating Parts of High Speed Engines." Geo. I. Alden.

No. 907, vol. xxii., p. 955: "Determination of Fly-wheels to Keep Angular Variation of an Engine within a Fixed Limit." J. I. Astrom.

Throw of connecting rod.

Shortness of connecting rod.

4. Of these the first three are of the greatest magnitude. The first causes the torque to pass through zero twice in each revolution, the second causes the torque to be less in the second half of a stroke or impulse than in the first. The effect of the reciprocating parts is to diminsh the torque in the first half of the stroke and increase it in the second half. Therefore, it is opposed to and counteracts the effect of expansion. The inertia effect is of considerable magnitude and frequently more than balances the effect of expansion. This is particularly the case in high-speed engines and in the low-pressure cylinder of a cross-compound engine, which is necessarily very large and bulky. The effect of the reciprocating parts is the most interesting, as it may be either harmful or beneficial—harmful in producing a peak at the end of the low-pressure stroke, where it overlaps the admission of the high-pressure stroke, thus merging the two impulses; beneficial in lowering the excess energy during admission of the high-pressure stroke.

5. In a single cylinder double-acting engine there are two impulses per revolution, and in a cross-compound engine there are four impulses. During the first part of the stroke the effort is less than the average, during the second part (equal to about one-half the period of the stroke) it is greater than the average. During the last part of the stroke the effort is less than the average again. This is shown diagrammatically in Fig. 17, Curve 1. Curve F is the varying crank effort or torque in foot-pounds at the centre of the shaft. The straight line AG represents the average value or mean effort. The difference between these two at any time represents the excess or deficit torque, or the force acting on the flywheel or given by the flywheel.

This force F, acting on the mass of the flywheel M, gives the wheel an acceleration $a = \frac{F}{M}$, or $a = \frac{F}{I}$, where I is the moment of the flywheel.

6. From a to b in the diagram the acceleration is negative and the speed drops (Curve 2), from b to d the accleration is positive and the speed rises, the gain in speed from minimum to maximum, (b to d) represented by S, being proportional to the area of the figure bcd, or it is equal to $\int adt$. The acceleration is negative

again from *d* to *e*, and the speed drops back to its original value at the end of the impulse to pass through a similar cycle in the next impulse.

7. While the speed is less than the average during the first half of the impulse (as from *a* to *c*, Curve *V*), any definite point of the

TORQUE, SPEED AND DISPLACEMENT
OF A SINGLE CRANK ENGINE.

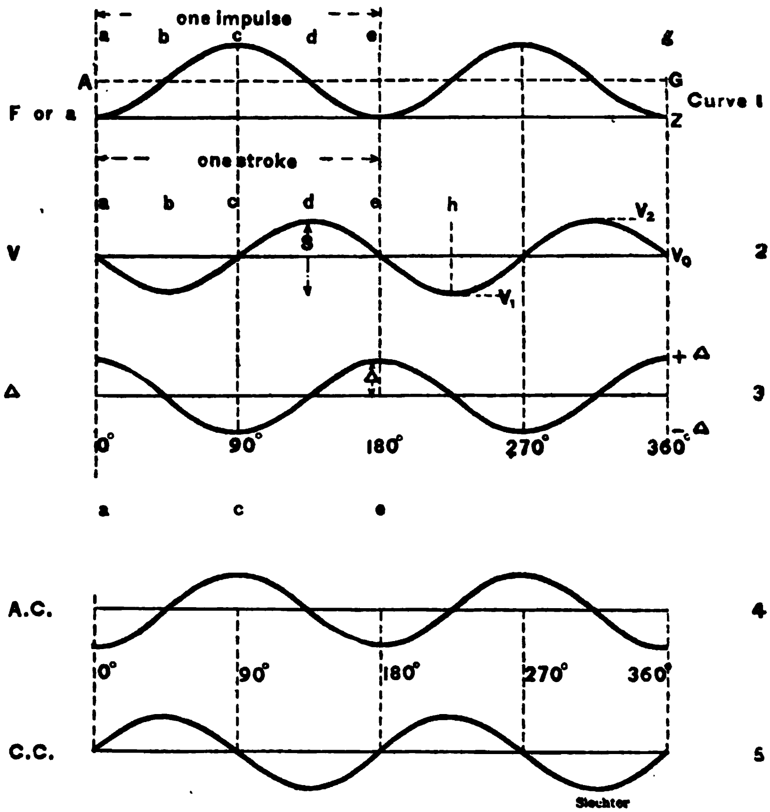


FIG. 17.

revolving masses, as the crank-pin centre, will fall behind the position it would maintain if the angular velocity were constant; and at *c*, where the speed becomes greater than the average again, it will have reached its greatest displacement and will commence to regain its correct position, which it reaches at *d* and passes to a displacement ahead of that of constant velocity.

The change of position from *c* to *e*, represented by 2Δ, is proportional to the area of the Curve V between c and e, or is equal to $\int vdt$.

8. Thus we find that the displacement angle is proportional to the double integral of the curve of unbalanced effort. This would be a long and tedious operation, but it is the only correct method of obtaining exact values. The method was given in the discussion on Mr. Astrom's paper. The work may be considerably shortened by the use of the integraph (of Coradi, Zurich), an instrument which will graphically integrate each curve in turn. By tracing the curve to be integrated with the pointer, a recording pointer will draw a curve, each ordinate of which is proportional to the area enclosed by the original curve up to that point. Its principal objection is that to get accuracy the original curve must be on a large scale, for the deduced curve is of such a scale that a one-inch ordinate represents at least four square inches of area in the original.

9. The displacement may be obtained approximately quite easily on the assumption that the curves are more or less regular and symmetrical, resembling sine curves. Let us represent the ratio of the area of the greatest peak of unbalanced energy to the rectangle representing the foot-pounds energy per revolution by k, where $k \times P = P_1$.

$$P = \frac{HP \times 33{,}000}{RPM}$$

k = unbalancing factor.
P_1 = unbalanced energy.
P = ft. × lbs. energy per revolution.
HP = output of engine.
RPM = speed of engine.

Then we have:

$$P_1 = \frac{W}{2g} \times (V_2^2 - V_1^2) = \frac{W}{2g} V_0^2 \times 2S = k \times P,$$

where W = effective weight of flywheel,
g = the constant, 32,
V_0 = average velocity of W,
V_2 = maximum " of W,
V_1 = minimum " of W,
$$S = \frac{V_2 - V_1}{V_0}.$$

S is the variation in speed shown in the diagram.

10. Having the value of S, we must assume that the maximum variation from mean is $\frac{S}{2}$ and the average value (from c to e) $\frac{S}{2} \times \frac{2}{\pi} = \frac{S}{\pi}$. This average value of S lasts during one-half of an impulse, or, if n is the number of impulses per revolution, while the crank-pin is passing $\frac{360}{2n}$ degrees. Therefore the change in position during this time is $2\Delta = \frac{S}{\pi} \times \frac{360}{2n}$, and $\Delta = \frac{S \times 360}{4\pi n}$.

Combining these formulæ so as to get Δ in terms of K:

$$\Delta = \frac{k \times P \times g \times 360}{W V_o^2 \times 4\pi n}.$$

This is the displacement of the crank-pin from mean.

11. In a bipolar alternator the E.M.F. performs a complete cycle for every revolution; in a four-pole machine there are two cycles per revolution; that is, there is a cycle for every pair of poles per revolution, and if there are p pairs of poles on an alternator one cycle of the crank corresponds to $p \times 360$ degrees in the electrical circuit. Thus, if α is the displacement (from mean) in the electrical circuit, then $\alpha = p \times \Delta$, or many times the displacement usually calculated and discussed. The effect produced in the electrical circuit is due to this displacement rather than to the variation in speed.

12. Two sine waves of a given amplitude E, if they differ in phase by B degrees, have a maximum difference of $2E \sin \frac{B}{2}$. Thus, if two generators differ in phase B degrees, an E.M.F. of this value is short-circuited through their joint impedance.

If we represent their full load current by unity, the short-circuit current would be about 2.5, and the impedance $\frac{E}{2.5}$. Then the cross current due to this displacement would be:

$$i = \frac{e}{z} = \frac{2E \sin \frac{B}{2}}{2 \times \frac{E}{2.5}} = 2.5 \sin \frac{B}{2}.$$

Assuming a value for this cross current of 10 per cent. of full load current as a reasonable allowance, we have:

$$2.5 \sin \frac{B}{2} = .10, \text{ whence } \frac{B}{2} = 2.30.$$

That is, a displacement of phase in the electrical circuit of 2.5 from mean will cause a cross current of about 10 per cent. of full load current to flow. Therefore we assume $\alpha = 2.5$ as the limiting value of the displacement. This cross current heats the windings of the generators and may cause considerable loss of power in the resistances of the connecting cables.

13. The value $\alpha = 2.5$ is one which builders of electrical apparatus have more or less generally agreed on as the limit, if satisfactory parallel running of apparatus is expected. If other conditions are favorable, such as low resistance between generators, and few synchronous motors in circuit, the generators will work well in parallel with a considerably greater displacement, but when the conditions become exacting 2.5 is the limit.

14. A synchronous motor or rotary converter having a constant load tends to run at constant speed and has more or less flywheel effect in its rotating member. If now this is connected to an alternator driven by an engine which has an irregular angular velocity, giving a displacement from + 2.5 to − 2.5, there will be a continual give and take of current between the two which may lead to the phenomenon known as hunting. That is, when the generator is ahead of the motor, the motor tries to catch up and takes power from the generator to do so; then, when the generator is behind in relative position, the motor tries to drag it along, and in so doing gives its power back again.

15. We have seen that the evil effect in the electrical circuit increases with p, the number of pairs of poles. Thus it is that high frequency generators give more trouble than low frequency generators. In most designs of engines the flywheel capacity necessary to carry the engine over a change in load while the governor is operating is sufficient to maintain the angular velocity within reasonable limits, but in cross-compound engines the inertia of the reciprocating parts of the low-pressure cylinder (the cylinder being so large) is usually so great that the crank effort diagram is much distorted. Instead of getting four peaks per revolution, we get two or three, and each of these peaks lasts longer,

the period of high speed lasts longer, and the displacement is greater.

16. There is also an aggravating action in the electrical generator itself, as pointed out by Mr. H. E. Longwell in a paper before the Engine Builders' Association last May. This is what may be called the synchronizing force, or torque, of the generator. As mentioned before, each generator, as well as each motor and rotary of the system, tends to keep in step with the rest of the system—that is, resists any displacement. If some external force causes a displacement, there occurs in the generator a torque proportional to the displacement, tending to bring the revolving part back to the mean position.

If the displacement is backward, as at *c* of Curve 3, Fig. 17, there will be a torque trying to pull the revolving part forward into step (as in Curve 4, Fig. 17), which torque it will be noticed is greatest where the displacement is greatest, and where the engine effort is greatest; thus the synchronizing torque of the generator is in step with the unbalanced effort of the engine and additive thereto.

17. Two generators connected in multiple will share the load between them at any instant in proportion to the angular displacement between them. If the displacement is not very great, the variation in load or, in other words, the synchronizing force in each is proportional to the sine of one-half the angle between them—that is, is proportional to the cross current. Thus we find that at 2.5 degrees displacement there is a torque equal to 10 per cent. of full-load torque tending to pull the alternator into step, and this torque occurs simultaneously with the excess effort of the engine and increases that excess and the unbalancing factor.

18. In the case of the 800-kilowatt set, the curves of which are given here as an example, we find a displacement of 3.4 degrees, due to unbalanced engine effort alone, and this displacement causes a synchronizing torque in the alternator varying up to 15 per cent. of full-load torque as a maximum. This increases the unbalancing factor 30 per cent., and would increase the displacement about the same amount. But this is an old plant and an unusually severe case (60 cycles). This shows that it does not necessarily follow that alternators of large synchronizing power will run in parallel better than those of small synchronizing power, but rather the reverse, though there are reasons why the other extreme is not desirable either.

It might be interesting here to note that in a continuous current machine this torque is proportional to the speed instead of the displacement. When the speed is high the torque is negative, and when the speed is low it is positive, or additive to the engine effort. This is shown in Curve 5 of Fig. 17. The effect of this torque is merely to distort the curve of engine effort, as it is displaced 90 degrees therefrom. It is interesting to note that this torque is just opposite in effect to that of the reciprocating parts at any given time.

19. From a number of engines I have analyzed, and from data collected from some German and French technical publications and different American engine builders, it may be considered reasonable to expect an unbalancing factor of:

.15 —.30 in a single-crank double-acting engine,
.075 — .15 in a two-crank engine.

But in the two-crank engine, as mentioned before, the distorted curve of effort usually gives only two displacements per revolution instead of the four we would expect; therefore we may say that the "apparent" unbalancing factor is .15 — .30. A three-crank engine has about the same apparent unbalancing factor as a two-crank.

A vertical engine gives a little more unbalancing than a horizontal, due to the dead weight of the moving parts, for which we should make some allowance.

20. To determine a weight of flywheel which would limit the displacement to a value approximately equal to 2.5, I have derived a formula based on the above unbalancing factors with a reasonable increase to allow for overloads. While not always giving the most desirable flywheel capacity, since it would be impossible to take into account all the irregularities of some engines, yet it gives a value suited to the various conditions, such as frequency of alternator, style of engine, etc., such that if the engine is reasonably good we will get the results desired. If this weight of flywheel does not give satisfactory results it would be much better (for the electrical circuit) to make such changes in the engine itself as to give a better crank effort diagram than to increase the weight of flywheel, for a flywheel may easily give trouble by being too heavy.

21. As changes in the engine, I might suggest:

First, as best though most difficult, changing the angle between the two cranks.

Second, changing the proportion of load taken by the different cylinders, and make the low pressure take more load.

Third, introduce compression at the end of the stroke to take up inertia, particularly in low-pressure cylinder.

The formula is:

$$Wr^2 = \frac{KW \times C \times 10^9}{S^4},$$

where W = effective weight of wheel,
KW = rating of generator,
S = speed of engine in R.P.M.,
r = radius of gyration,
C = a constant as follows:

	Horizontal Single-crank.	Vertical Cross-compound.	Horizontal Cross-compound.
25 cycles................	315	275	250
40 "	505	440	400
50 "	630	550	500
60 "	755	660	600
125 "	1575	1380	1250

22. In some cases it is necessary to use a larger flywheel than this to carry the load during the short time it takes for the governor to operate. In railway power stations the load varies so greatly and so suddenly that an immense flywheel has to be adopted to meet these changes and the angular displacement has to be ignored. But so far as hunting and parallel operation are concerned, too great a weight of flywheel is almost as undesirable as too little, for a large inertia in the circuit means that much power must be expended in bringing any oscillating mass back into synchronism. Therefore, where a very heavy flywheel is not necessary for definite reasons, it is desirable to keep the weight down, and the weight necessary to limit the displacement to 2.5 degrees will be found a reasonable, medium value.

23. In many cases where hunting has occurred due to a pulsating prime mover or other cause, it may be held in check and practically suppressed by connecting a dashpot to the governor mechanism. This dashpot should have the characteristics that it is not sensitive to sudden changes in load or speed but that any prolonged change will cause it to move. This has been used successfully in practice to a considerable extent.

24. To determine by test the variation in speed of an engine is a very delicate and complicated experiment, and there have been many ways tried and suggested, but with very little success. At the meeting of the French Société Internationale des Electriciens last winter this subject was discussed and many methods described. The most successful was that of E. W. Mix, in which a bevel-gear wheel is driven from the engine shaft by some very positive method—as gearing, or a bicycle wheel pressed against the engine flywheel. This gear wheel drives in opposite directions two other bevel gears on concentric shafts at right angles to the shaft of the first gear. The outer hollow shaft of these two concentric shafts drives a light aluminum disk. The other gear-wheel is connected to a shaft consisting of a long elastic steel wire, and this drives a disk with a heavy flywheel rim. These two disks are placed side by side. One being light and connected by a rigid shaft, follows all the irregularities of the prime mover; the other, having considerable inertia and being driven by an elastic connection, revolves at practically constant angular velocity. There are slits in both disks, and by an arrangement of a light and mirror the relative displacement of the slits causes a beam of light to be deflected.

25. If an alternator becomes very much displaced in phase it may absorb power electrically and drag the engine along. If now the governor does not meet the condition properly, there may be no steam admitted to the cylinder; then at the end of the stroke the vacuum in the cylinder may be sufficient to draw water from the condenser, which may cause damage. Electrical damping devices are used in many cases to overcome these irregularities. They consist of short-circuited windings on the poles of the alternator. When the alternator oscillates ahead of or behind its correct speed, currents are generated in these devices which tend to oppose these oscillations. This is quite effective if the oscillations are rapid or of a short period, but, of course, it wastes power just in proportion as its effectiveness increases, being nothing more than a friction brake.

26. To give an idea of the flywheel capacity required to meet the requirement advocated and show that, contrary to the general opinion among mechanical engineers and engine builders, a very heavy wheel is not necessary, I append a table giving a comparison of the weights calculated by the above formula and those actually installed by the engine builders.

	Installed.	Calculated.
Altoona	13,000	11,000
Cleveland	41,000	75,000
Glasgow	148,000	164,000
Hanover	40,000	58,000
Baltimore	73,000	45,000
Metropolitan	240,000	193,000
Washington	15,100	17,500
Philadelphia	70,000	107,000
Omaha	24,000	18,000
Santa Catalina	34,000	21,000
Tornavento	72,000	44,000
Santiago	17,000	13,300
Milwaukee	50,000	40,000

Explanation of Diagrams.

27. I have given attached the curves of a horizontal cross-compound engine, cylinders 24 inches and 48 inches, by 48 inches stroke, which is direct-connected to a 60-cycle alternator of 800 kilowatts at 100 revolutions per minute. There were several of these in the station and there was considerable trouble from "hunting." It was finally necessary to put short-circuit windings on the poles and a dash-pot governor on the engine, since which time the plant has run satisfactorily. The plant was laid out several years ago.

28. The irregular shape of the curve of combined high and low pressure crank efforts will be noticed. There are practically only two impulses per revolution. The maximum unbalancing factor is .095, is negative, occurs during the (high-pressure) return stroke, and lasts for 126 degrees, or over a third of a revolution; this is the cause of the poor characteristics of the engine. If dead weight were added to the high-pressure piston the diagram would be improved, or if the angle between the cranks were less.

By integrating this curve of crank effort we get the velocity curve as shown, and by integrating this in turn we get the curve of displacement of the crank centre, which shows very clearly the "two impulse" effect of the engine.

The maximum displacement is .095 degree. The generator has 72 poles; hence the displacement in the electrical circuit is $36 \times .095 = 3.4$ degrees.

29. In Fig. 19, Curve 1, is shown α, the displacement, and the broken line shows the variation in synchronizing force. In the

lower part of the figure we have in full lines the crank effort diagram, and curve *e* is the synchronizing torque of the alternator in

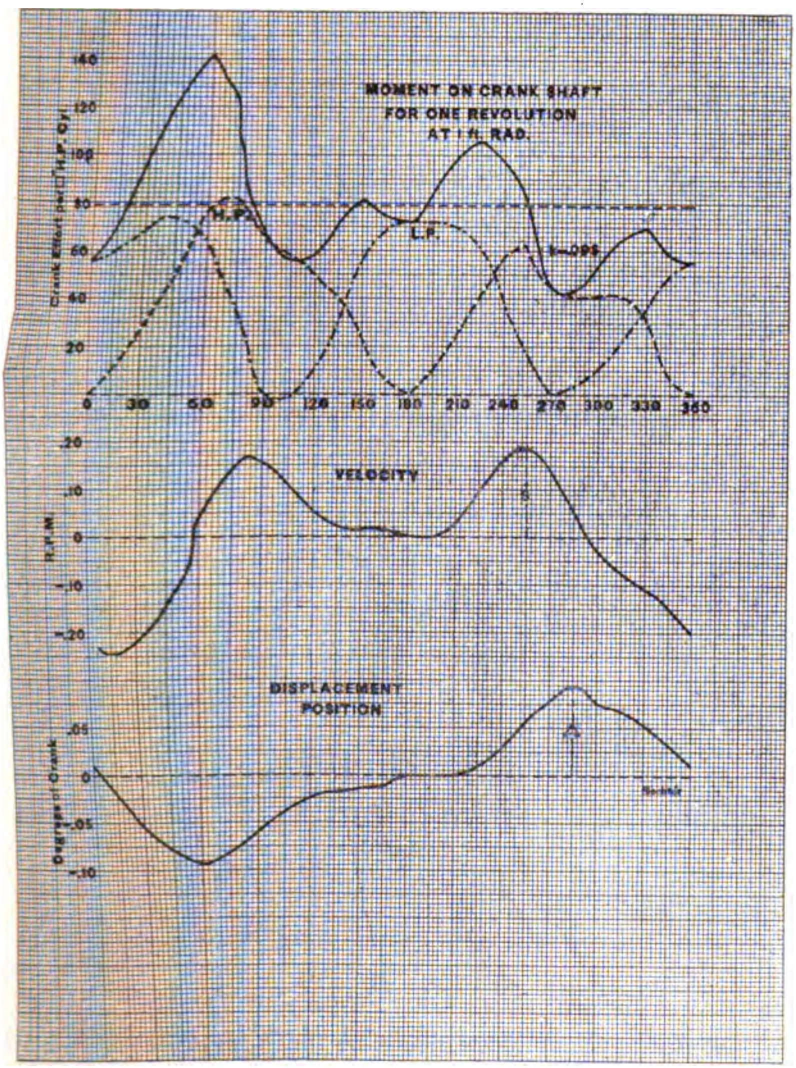


FIG. 18.

foot-pounds. Adding these two together, we get the resultant unbalancing torque, which, as mentioned before, gives an unbalancing factor of .123, or 30 per cent. greater than that due to

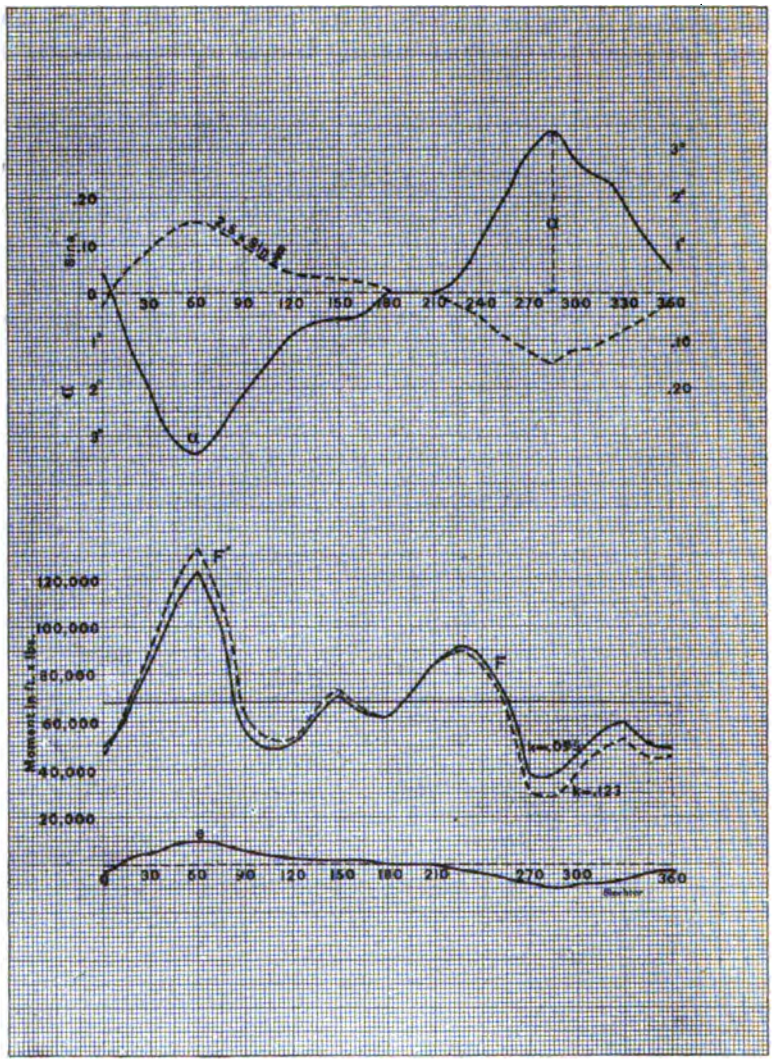


FIG. 19.

the engine alone. In these diagrams the high-pressure cylinder takes 47.5 per cent. of the load and the low-pressure cylinder 52.5 per cent.

DISCUSSION.

Mr. Henry E. Longwell.—In paragraph No. 12 it is stated that if we represent the full load current of the generator by unity, the short circuit current would be about 2.5 and the impedance $\frac{E}{2.5}$. I do not see why the short circuit current is necessarily 2.5 or anywhere near it. It seems to me that the short circuit current is a question of the design of the generator, and might be anything within reasonable limits—say, from 2 to 5 times the normal full load current. Would it not be a more exact way of putting it to say:

If we represent their full load current by unity, *and the short circuit current is 2.5 times full load current, the impedance will be* $\frac{E}{2.5}$ *and the cross current due to this displacement, etc.*

I presume that in the first equation of paragraph 12, $i = \frac{e}{z}$ that

i = the cross current due to the electromotive force caused by the displacement of the phases of the two generators.

e = this electromotive force which is $2\,E \sin. \frac{B}{2}$.

z = twice the impedance of one alternator.

As long as generators are built with different short circuit characteristics, and it is desired to limit the cross current to 10 per cent. of full load current, it would seem desirable to use a more general formula in which x would equal the short circuit current and $\frac{E}{x}$ the impedance.

The short circuit current would then equal x Sin. $\frac{B}{2}$, and the displacement giving 10 per cent. cross current would be such that

$$\text{Sin. } \frac{B}{2} = \frac{0.10}{x}.$$

Inasmuch as the effect of the synchronizing force is to augment the unbalancing moment in the engine, which in turn increases the displacement, we are not so much concerned with the initial displacement due to the engine alone, as with the final displacement due to the aggravating influence of the synchronizing force.

Coincident with my own paper on this subject, referred to in paragraph 16, Mr. E. Rosenberg, chief engineer for the firm of Körting Brothers in Hanover, Germany, published in the *Electrotechnische Zeitschrift* (Nos. 20–22 for 1902), a very much more practical and exhaustive paper on the same lines. An English translation has been promised, but I have not as yet seen it.

In brief, however, Mr. Rosenberg shows very clearly that no invariable rule can be laid down for the initial displacement due to the engine alone, as even with the same synchronizing force between the generators, the amount that the initial displacement is augmented by the synchronizing force varies with the type of the engine.

A single-crank engine will permit of a greater initial displacement than an engine having two or more cranks, and a single-cylinder, single-acting, four-cycle gas engine will admit of a still greater displacement.

The amount that the synchronizing force will augment the initial displacement depends on the magnitude of this synchronizing force as compared with the unbalanced torque in the engine.

In a single-cylinder, single-acting, four-cycle gas engine the unbalanced torque in the engine would be very great, and the torque due to the synchronizing force resulting from a displacement of 2.5 electrical degrees would be quite insignificant in comparison.

On the other hand, in a three-crank, double-acting steam engine, the unbalanced torque might be less than the synchronizing torque resulting from an initial displacement of 2.5 electrical degrees.

In the first case the augmentation of the initial displacement by the synchronizing force would be trifling, while in the second case the initial displacement would be increased indefinitely until the generators pulled apart.

Mr. Slichter has shown that for a certain 800 kilowatts, 60-cycle alternator with 72 poles, running at 100 r. p. m., with a displacement of 3.4 electrical degrees due to the engine alone, the synchronizing force increases the unbalanced force in the engine itself by about 30 per cent. By the double integration of the new curve of moments we would get a new displacement curve of about 30 per cent. greater amplitude. This in turn would again increase the unbalanced turning moment and give rise to still another displacement curve. The final displacement would be roughly the summation of an infinite series in which each increment was 30 per cent. of the one preceding. In other words, the total displacement would be

3.4 + 1.02 + 0.3 + 0.1 + * * * * * * * * = about 4.9 degrees.

It is easy to imagine that we might have another type of engine of the same power and speed, which would give a crank effort curve enough more uniform to make the unbalancing factor .0475 instead of .095. If the flywheel were enough lighter to make the displacement the same as in the first case, the synchronizing torque would increase the unbalancing factor in the engine 60 per cent. instead of 30 per cent. The ultimate displacement starting with the same initial displacement would then be

3.4 + 2.04 + 1.22 + 0.73 + 0.45 + 0.27 + 0.16 + 0.09 + * * * * * * * * = about 8.4 electrical degrees.

The mathematical treatment of the problem, either as regards the determination of the irregularity in the speed of the flywheel, or the electrical disturbance in the generator, can hardly be relied upon to give us dependable quantitative results.

We all know the uncertainties as regards the engine itself—a possible error in estimating the weight of the reciprocating parts, or a variation in the steam distribution from that we have assumed, or perhaps an unfortunate choice as to the proper load on which to make the calculations. While we now make these involved and tedious caculations, we always discredit the results by multiplying them by two or three to cover uncertainties.

The electrical calculations are also unreliable, as they are based on three assumptions, none of which can be regarded as absolutely true. These assumptions are:

(*a*) That the pole pieces are spaced with absolute mathematical accuracy.

(*b*) That the magnetic centre of each pole coincides exactly with the geometric or mechanical centre.

(*c*) That the electromotive force is represented by a true sine curve.

The mathematical investigation is, however, exceedingly valuable in that it gives us a true insight as to the general character of the conditions we have to meet, and their mutual relations on each other. It moreover gives us something on which to base our judgment as to the amount of flywheel effect necessary, but the actual weight of flywheel required is none the less a matter of judgment.

I do not doubt that we shall soon use an empirical rule for the flywheel, something of the form suggested by Mr. Slichter in paragraph 21. Such a formula will doubtless be deduced from data taken from a number of generating units which are running in parallel satisfactorily. It will doubtless contain a factor for the short circuit current of the generator, and will perhaps not favor one type of an engine more than another as does the formula given.

There is no such thing as absolute perfection in the parallel operation of alternators direct-connected to reciprocating engines, and we can only hope to reach the point where the concensus of opinion is that the results are good enough.

I can see no theoretical limit to the amount of flywheel that can be used to good effect. When the alternators are once coupled in parallel, it would seem that the more flywheel we have the better would be the operation. In the act of cutting an alternator in on the general system, however, the heavier the flywheel the greater the care which must be taken to have it running at the correct speed when the switch is closed, to prevent the shock due to the sudden acceleration or retardation of a large mass.

*Mr. Walter I. Slichter.**—In reply to Mr. Longwell's criticism of the value used for the short circuit current of the alternator in the paper, I would say that that is an average value of many different machines which I have analyzed. I have before me now the tests on twenty different machines, taken at random. The maximum value of the short circuit current shown by these is 3.74 times the full load current, the minimum 1.52 and the average 2.58. Therefore I claim that this is a reasonable value on which to base calculations. A change in the value of the short circuit current from 2.5 to 3 would increase the cross current from 10 per cent. to 12 per cent. for the given displacement, and would increase the synchronizing torque 20 per cent., and this in turn, then, would increase the final unbalancing factor some 10 per cent. Now, the change in the unbalancing factor due to the cut-off changing with the load, is much greater than this. Thus I consider it an unneccessary refinement.

Of course, the formula would be more accurate if such a constant as Mr. Longwell proposes were introduced, but it is questionable if the gain in accuracy would warrant the complication. There are other conditions which are more variable.

The object in putting forth this formula is not to set a hard and fast rule, but to calculate a value which would come within

---

*Author's closure, under the Rules.

the lines of good practice, for I have known of many cases where flywheels have been proposed, and even installed, which were very far from a reasonable value, due to a misconception of the properties of the alternator.

This formula is not deduced from theory, but is based on practice as will be seen by the table of values given. The mathematics is merely introduced to show the relative importance of the different factors and the way in which they enter.

Mr. Longwell's discussion of the cumulative effect of the synchronizing torque is very interesting, and it is very possible that this has been the cause of considerable trouble. It is one of the reasons why a two-crank engine connected to a given alternator must have more than one-half as much flywheel weight as a single-crank engine.

No. 957.*

THE DEFLECTION OF BEAMS BY GRAPHICS.

BY WILLIBALD TRINKS, YOUNGSTOWN, O.
(Non-member.)

1. THE method of designing machinery considering strength alone is rapidly becoming obsolete. On the other hand the importance of rigidity, that is smallness of deformation, is appreciated more and more, and it is often desirable to predetermine the deflection which will take place in a certain part of a new machine. The easiest way to accomplish this task is of course by comparison with corresponding parts of similar machines, the deflections of which have been measured; but there will invariably occur cases where such a procedure is impossible, either because results of measurements are not available, or because the machine to be calculated is so different in style or size from anything previously constructed, that comparisons would be unreliable. In such an instance there is nothing left but a guess or a calculation, and the latter is much the safer way.

2. But, while the calculation of parts with regard to strength is comparatively simple, and formulas and directions for dimensioning parts to sustain a given load can be found in most reference books, the analytical calculation of the deformation of the same parts becomes at once helplessly complicated and extremely difficult, so that, as a rule, only very rough approximations can be obtained. However, it is entirely unnecessary to abide with crude and imperfect results, because there exist several graphical or semi graphical methods which give comparatively accurate results without complex calculations. The full comprehension of these methods demands the knowledge of the elements of the calculus, which probably accounts for the fact that they are not as widely known as they deserve to be. But, as their application is much easier and at the same time more accurate than that of the common analytical methods, it will be tried in the following to present

* Presented at the New York meeting (December, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

three of the more important methods in a suitable manner for everyday use of the practical engineer and draftsman.

3. Of course it is impossible to repeat here the whole theory of the flexure of beams, so we shall start with the following fundamental relation, the deduction of which can be found in any reference book:

$$d\tau = \frac{M}{EI} dx \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

In this equation dx is a small length of a beam (Fig. 20); M the bending moment caused by the external forces (*i.e.*, applied loads and reactions), and I the moment of inertia, both with reference

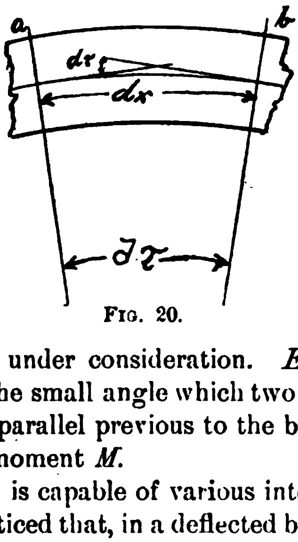


FIG. 20.

to the beam-element under consideration. E is the modulus of elasticity and $d\tau$ is the small angle which two consecutive sections a and b (which were parallel previous to the bending) make under the influence of the moment M.

4. The formula (1) is capable of various interpretations.

First, it will be noticed that, in a deflected beam, there is a small angle $d\tau$ between every two consecutive sections (see Fig. 21), so that the angle τ, which the two end sections of the beam make, is equal to the sum of all the small angles $d\tau$, or

$$\begin{aligned} \tau &= d\tau_1 + d\tau_2 + d\tau_3 + \text{etc.} \\ &= \int d\tau \\ &= \int \frac{M}{EI} dx \end{aligned}$$

General equations for the deformation of beams can only be deduced under the supposition that the beam is prismatic, that is I is constant over its entire length; but in reality this seldom occurs. As a rule I is variable and it becomes therefore necessary to combine the two variables M and I in such a manner that they appear as a single variable depending upon the value of x. To this end we select that moment of inertia I_o, which is constant over the greatest length of the beam, as a moment of inertia of reference, and reduce the values of the bending moments over the rest of the beam in the ratio $\frac{I_o}{I}$. Take, for example, Fig. 22, which represents a shaft of two diameters d_o and d_1, resting in two bear-

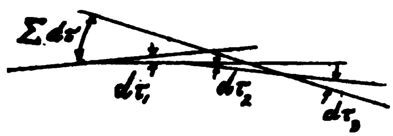


FIG. 21.

ings a and b, and carrying two loads P and Q. From statics it is known that the bending moment under P is (with the notations of Fig. 22)

$$M_p = \frac{x_1}{l}(Px_3 + Qx_4)$$

and that the bending moment under Q is

$$M_q = \frac{x_4}{l}(Px_1 + Qx_2)$$

5. If these values be laid off to a convenient scale as vertical ordinates 12 – 2 and 13 – 3 from a horizontal axis 1 – 4, the broken line 1 – 2 – 3 – 4 – 1 represents the magnitude of the bending moment at any section and is called the polygon of bending moments for the external forces. Similarly the polygon 1 – 16 – 17 – 4 is obtained as a curve of bending moments caused by the weight W of the beam.

The moment of inertia $I_o = \frac{\pi}{64} d_o^4$ is constant over the greatest length of the beam and will therefore be selected as a moment of inertia of reference. Throughout the length 9 – 10 (corresponding to the constant diameter d_o) the polygon of bending moments is not altered, but the ordinates of the polygon over the abscissæ 1 – 9 and 10 – 4 (corresponding to the smaller diameter d_1) are enlarged in the ratio $\frac{I_o}{I_1}$, so that for example $\frac{5-9}{6-9} = \left(\frac{d_o}{d_1}\right)^4$. This gives the polygon 1 – 5 – 6 – 2 – 3 – 7 – 8 – 4, which is the polygon of bending moments reduced to a constant moment of inertia, viz. I_o, and which will be called the M'-polygon. Having that,

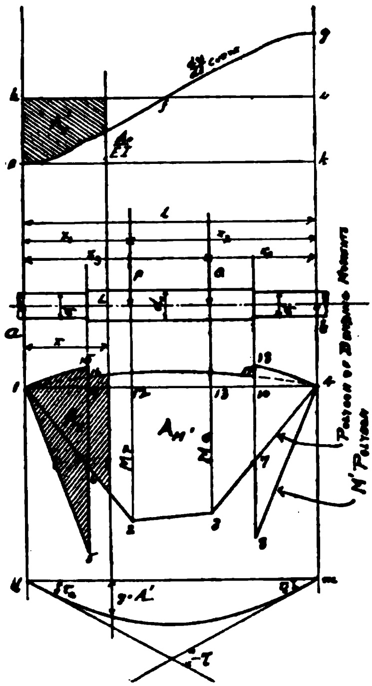


FIG. 22.

we can proceed as though we had a beam of constant cross-section, and obtain

$$\tau = \frac{1}{EI_0}\int M'dx \quad .$$

6. But $\int M'dx$ denotes only the area $1-5-6-2-3-7-8-4-18-17-16-15-1$, or A_m'; thus we have

$$\tau = \frac{A_m'}{EI_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The area A_m' can be measured with the aid of a planimetre.

As an illustration, the following numerical example will be considered.

(For notations see Fig. 22).

$P = 90,000$ pounds.
$Q = 70,000$ "
$W = 25,500$ "

$x_1 = x_4 = 85$ inches.
$x_2 = x_3 = 147$ "
$d_o = 24$ inches.
$d_1 = 20$ "
$E = 30 \times 10^6$ pounds per square inch.

7. With these figures we obtain :

$$\left.\begin{aligned} M_p &= \frac{x_1}{l}(Px_2 + Qx_4) = 7\,030\,000 \text{ pound inches} \\ M_q &= \frac{x_4}{l}(Px_1 + Qx_4) = 6\,560\,000 \quad \text{"} \quad \text{"} \\ M_w &= \tfrac{1}{8} W(x_1 + x_2) = 740\,000 \quad \text{"} \quad \text{"} \end{aligned}\right\} \text{Bending moments.}$$

$$\left.\begin{aligned} I_o &= \frac{\pi}{64} 24^4 = 16\,300 \\ I_1 &= \frac{\pi}{64} 20^4 = 7\,850 \end{aligned}\right\} \text{Moments of inertia.}$$

$$\frac{I_o}{I_1} = 2.07$$

$$\frac{M_p}{EI_o} = \frac{1.42}{100000 \text{ inches}};$$

$$\frac{M_q}{EI_o} = \frac{1.34}{100000 \text{ inches}};$$

$$\frac{M_w}{EI_o} = \frac{0.15}{100000 \text{ inches}}.$$

In Fig. 23 the polygons of bending moments are drawn above the axis for the weight of the shaft, and below the axis for the applied loads. Scale for distances: 1 inch represents 100 inches; scale for $\frac{M}{EI}$: 1 inch represents $\frac{2}{100000 \text{ inches}}$; hence 1 square inch of the area of the polygon represents an inclination of $\frac{2 \times 100 \text{ inches}}{100000 \text{ inches}}$ $= \frac{1}{500}$. The total section-lined area amounts to 1.38 square inches (measured with a planimetre), and therefore the angle τ (Fig. 22) has the value $\frac{1.38}{500} = \frac{2.75}{1000}$; or, in degrees: $\tau = \frac{2.75 \times 180}{\pi \times 1000} = 0.157$ degree.

8. It will be observed that this procedure gives only the angle which the tangents to the elastic curve at the extreme sections of the beam make with each other; but not the angles which these

tangents make with the horizontal (centre line of bearings in case the beam is a shaft) unless the distribution of loads and material is symmetrical to the centre line. For this reason the knowledge of the angle τ is sufficient only for rough approximations. When it is desired to know either the slope at the ends or the deflection of the beam, we have to proceed a little further and draw the elastic curve, that is the shape of the neutral surface of the

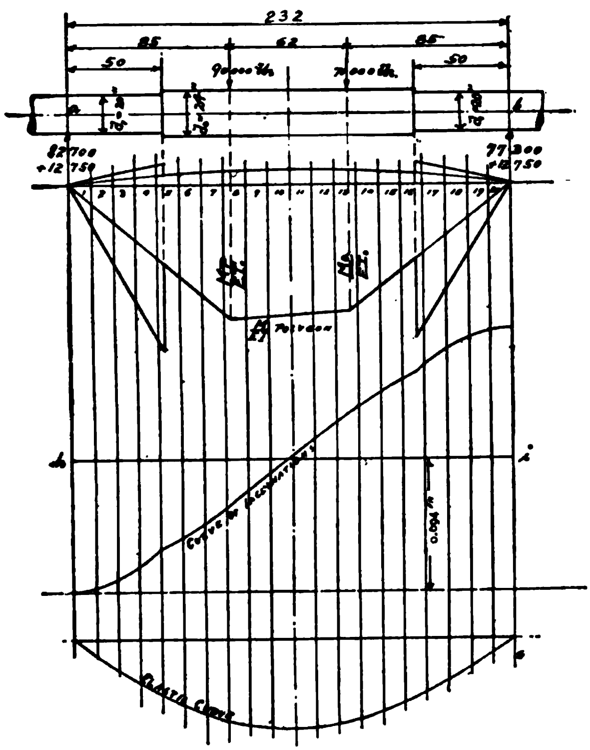


FIG. 23.

loaded beam. To this end we return to the equation (1) $d\tau = \frac{M}{EI}dx$, which forms the base for all the following deductions. The result of the little calculation made above demonstrates that in all practical cases τ is an extremely small angle; but for such angles τ is equal to tan τ without noticeable error; for example,

$$1 \text{ degree} = 0.017453$$
$$\tan 1 \text{ degree} = 0.017455.$$

Therefore equation (1) may be written

$$d\,(\tan\tau) = \frac{M}{EI}dx.$$

9. The differential calculus teaches that for any curve $\tan\tau = \frac{dy}{dx}$; substituting this value, we obtain

$$d\left(\frac{dy}{dx}\right) = \frac{M}{EI}dx, \text{ or}$$

$$\frac{dy}{dx} = \int\frac{M}{EI}dx + C \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

In order to utilize this equation, we use the same process as above and combine the two variables M and I into one variable depending upon x, that is we distort the polygon of moments in the ratio $\frac{I_o}{I}$, and thus obtain the M'-polygon, see Fig. 22. Then equation (3) may be written:

$$\frac{dy}{dx} = \frac{1}{EI_o}\int M'dx + C \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

10. But for any point L, the expression $\int M'dx$ represents the section-lined area A_x of the M'-polygon between the origin and the ordinate belonging to x, which area may either be calculated, or, what is more convenient, be measured with a planimetre. With this notation we obtain

$$\frac{dy}{dx} = \frac{A_x}{EI_o} + C \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Now let us divide the length of the beam into a number of equal parts (say 20), then compute the value of $\frac{A_x}{EI_o}$ for each part, care being taken to measure each A_x from the origin or point 1, and finally set off these values to a convenient scale as ordinates of x. Thus we plot a new curve efg, the $\frac{dy}{dx}$ curve, or curve of inclinations. Returning to equation (4), it will be seen that C, the constant of integration, has to be eliminated. This is done by measuring the areas $efgke$ of the $\frac{dy}{dx}$ curve, then dividing the obtained value by the length ek, which gives the ordinate $C = eh$, and drawing hi parallel to ek. The proof of the correctness of this method will be given below. Then $he = \tau_a$ and $ig = \tau_b$; τ_a and τ_b being the angles which the elastic curve makes with the line lm at the supports. To find the ordinates y of the elastic curve from the $\frac{dy}{dx}$ curve, it must be remembered that

$$y = \int \frac{dy}{dx} dx + C_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6).$$

11. This equation is identical in form with equation (4), hence the ordinates y can be determined from the $\frac{dy}{dx}$ curve in the same manner, as the values of $\frac{dy}{dx}$ were found from the M' curve; that is by measuring the areas A_x', Fig. 22. The values of these areas, divided by the respective scales for height and length, are the ordinates of the elastic curve. Evidently the ordinate of the elastic curve at the right support is zero only when the area hef is equal to the areas gif, which proves that eh was the proper value for the constant of integration C. As to C_1, the second constant of integration, it is obviously equal to zero, because the elastic curve must pass through l and m, the centres of gravity of the end sections.

12. Although these deductions seem to be rather uninteresting and purely theoretical, their application is very simple and the practical results are valuable, as will be seen from the following numerical example:

To facilitate understanding, the example commenced above in Fig. 23 will be continued. The illustration shows under the sketch of the shaft the distorted polygon of bending moments, below this the curve of tangents and at the bottom the elastic curve. It will be noticed that the $\frac{M}{EI}$ polygon has been divided into twenty strips of equal width. The areas of the polygon lying between the left origin and the ordinate at the right of each strip are entered into Table I. in the column headed: Area of $\frac{d^2y}{dx^2}$ curve. Since 1 square inch represents an inclination of $\frac{1}{500}$, the tangents corresponding to these areas are found by dividing the values in column 1 by 500. The resulting values, multiplied by 1000, are entered in the second column under the heading: 1000 $\times$ $\frac{dy}{dx}$. With these figures the curve of tangents is drawn on a scale of 1 inch representing an inclination of $\frac{2}{1000}$. Multiplying this with the scale for distances (in which 1 inch = 100 inches) we obtain the scale for the areas of the inclination curve, namely 1 square inch represents $\frac{2 \times 100}{1000}$ inch = $\frac{1}{5}$ inch. The total area under the inclination curve measures 1.61 square inches; the length of

TABLE I.

	Area of $\frac{d^2y}{dx^2}$ curve.	$1000 \times \frac{dy}{dx}$.	Area of $\frac{dy}{dx}$ curve.	$10 \times y$.
1	0.015	0.03	0.09	0.18
2	0.055	.11	0.17	.34
3	0.125	.25	0.24	.48
4	0.215	.43	0.29	.59
5	0.28	.56	0.35	.70
6	0.375	.71	.38	.77
7	0.435	.87	.43	.86
8	0.525	1.05	.45	.90
9	0.615	1.23	.46	.92
10	0.705	1.41	.47	.94
11	0.795	1.59	.46	.92
12	0.88	1.76	.44	.89
13	0.97	1.94	.41	.83
14	1.04	2.08	.38	.76
15	1.11	2.21	.33	.67
16	1.18	2.36	.28	.56
17	1.26	2.52	.21	.43
18	1.32	2.64	.15	.30
19	1.36	2.73	.06	.13
20	1.37	2.75	.005	.00

the abscissa is 2.32; hence the height of the mean ordinate is .694 inch. The amounts of the areas in square inches between the inclination curve and the line hi are entered in column 3 of Table I. under the heading: Area of $\frac{dy}{dx}$ curve. It will be observed that the figures increase from zero to a maximum, and then decrease again. The fact that the last figure is 0.005 instead of zero is due to inaccurate readings of the planimetre. But, as the error amounts only to 0.5 per cent. of the greatest value, no attempt will be made for correction. As above found 1 square inch represents $\frac{1}{5}$ inch, hence we obtain the ordinates of the elastic curve by dividing the figures in the third column by 5. The tenfold values of the ordinates are given in the fourth column of the Table, and in addition they are laid off half size on the strips to which they belong, thus giving a (rather distorted) picture of the elastic curve.

13. This curve is almost symmetrical to the centre line, although the load is eccentric. The slope at the ends is found from the inclination curve as $\tau_a = \frac{1.39}{1000}$ or $\frac{1.39 \times 180}{\pi \times 1000} = 0.0797$ degree at the left end, and as $\tau_b = \frac{2.75 - 1.39}{1000} = \frac{1.36}{1000}$ or $\frac{1.36 \times 180}{\pi \times 1000} = 0.078$ degree at the right end. These angles are almost alike. The greatest deflection is 0.94 inch or about $\frac{1}{10}$ inch.

14. For simplicity the elastic curve has thus far been determined under the assumption that applied loads and reactions are concentrated forces, and that the shaft is perfectly free to deflect. In truth loads and reactions are (approximately) uniformly distributed over a certain length, and the shaft is to some extent stiffened from being tightly fitted in the hubs of the rope-pulleys, fly-wheels, etc. As proof that these apparent complications do not offer any difficulty whatever, if the described method is employed, Fig. 24 has been drawn, which takes the aforesaid facts into consideration. After the foregoing explanations a brief comment will be sufficient.

To find a moment diagram for uniformly distributed loads, draw the polygon for concentrated loads, and round the sharp corners by parabolas which are tangent to the straight lines of the polygon at the intersections with the verticals which enclose the uniformly distributed loads, see A-B, CD, EF, and GH in Fig. 24. Let the length of the hubs of the rope-pulleys be 40 inches and their outside diameter likewise 40 inches; the main bearings are 32 inches long. The moment of inertia for a circle of 40 inches diameter is 125.700, which is 7.7 times our standard moment of inertia, and therefore the ordinates of the bending moments are reduced in that ratio under the hubs. Strictly speaking this is not quite correct, because the modulus of elasticity of cast iron differs from that of steel. But as we neglect the reinforcing effect of the arms and as the influence of the reduced $\frac{M}{EI}$ area on the total deflection is relatively small, there would be no practical gain in taking the above mentioned difference of the moduli of elasticity into consideration.

With the figures given in Table II. the inclination curve and the elastic curve have been constructed in the same manner as before. As might be expected, the latter looks decidedly different from the curve drawn in Fig. 23. Probably Fig. 24 corresponds more nearly

TABLE II. (SEE FIG. 24.)

	Area of $\frac{d^2y}{dx}$ curve.	$1000 \times \frac{dy}{dx}$.	Area of $\frac{dy}{dx}$ curve.	$10 \times y$.
1	0.002	0.005	.06	0.12
2	0.015	.03	.11	.23
3	.06	.12	.16	.33
4	.14	.28	.22	.44
5	.24	.48	.24	.48
6	.31	.63	.25	.51
7	.33	.67	.27	.54
8	.34	.69	.28	.56
9	.36	.72	.29	.59
10	.45	.90	.30	.60
11	.53	1.07	.29	.59
12	.54	1.09	.28	.56
13	.55	1.11	.26	.53
14	.57	1.15	.25	.50
15	.64	1.28	.22	.45
16	.74	1.48	.10	.39
17	.81	1.63	.15	.31
18	.86	1.72	.10	.21
19	.87	1.75	.05	.10
20	.88	1.76	.005	.000

to the true conditions than Fig. 23; but in actual practice it has been customary to neglect the stiffening influence of the hubs.

15. From a purely theoretical standpoint the method of finding by direct mensuration, first the inclination curve and then the elastic curve is perfect and beyond reproach, but from a practical standpoint two objections must be made; first, that it takes too much time, and second, that the accuracy of the planimetre is limited. Therefore, in most cases it is preferable to use the following, entirely graphical and much simpler method which is known as "Mohr's method" or "Mohr's theorem," and which is

based on the properties of the equilibrium polygon which has also been termed "funicular polygon" by some English writers.

16. This neat and elegant method will be readily understood by investigating the influence which the deformation of a small element dx has on the shape of the beam, see Fig. 25. Consider only the small element dx as flexible, and the rest of the beam, viz., the two parts x and x' as perfectly rigid. Suppose that we

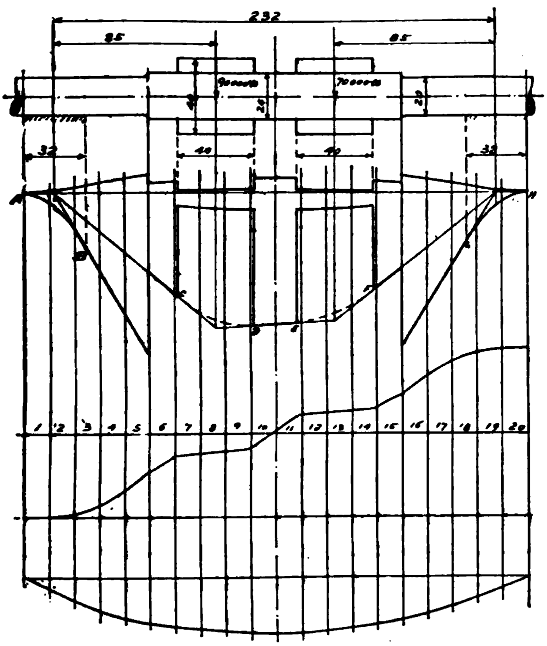


FIG. 24.

have deflected the beam so that the two rigid parts x and x' make the very small angle $d\tau$ with each other. Then the beam will assume the shape of the line acb, Fig. 25. The resulting, very small deflection $d\delta$ is found by a simple mathematical operation

$$d\delta = xd\alpha = x'd\beta$$

$$d\alpha = \frac{x'}{x}d\beta = d\tau - d\beta$$

$$\left(\frac{x'}{x} + \frac{x}{x}\right)d\beta = d\tau$$

$$d\beta = d\tau \frac{x}{x + x'}$$

$$d\delta = \frac{xx'}{x + x'}d\tau$$

But from equation (1) we know that $d\tau = \frac{M}{EI}dx$, hence we have

$$d\delta = \frac{xx'}{x + x'}\left(\frac{M}{EI}\right) dx \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

17. Now let us compare this result with the bending moment which is caused in the same beam by the element $g\,d\,x$ of a load curve. Those readers who are interested in the present discussion will undoubtedly know that the very small bending moment caused by the small concentrated load $g\,dx$, where g is the load in pounds per linear unit at the element under consideration, is

$$dM = \frac{xx'}{x + x'}g dx \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

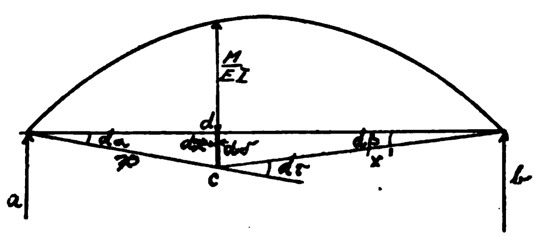


FIG. 25.

They will furthermore know that the diagram of the bending moment which is due to the concentrated load $g\,d\,x$ is represented by the triangle $a\,c\,b$, Fig. 26. It will thus be seen that the loading of a beam with $g\,dx$ pounds, Eq. (8), and the bending with $d\tau = \frac{M}{EI}dx$, Eq. (7), are mathematically identical, and that the effect of the value $\frac{M}{EI}dx$ on the shape of the elastic curve is identical with the effect of the load $g\,d\,x$ on the shape of the moment-diagram. For this reason the expression $\frac{M}{EI}dx$ has been termed "the elastic weight."

18. Since the elastic curve bears exactly the same relation to the $\frac{M}{EI}$ curve which the M curve bears to the load curve, it can obviously be obtained in precisely the same manner that the M curve is found from the load curve, that is by drawing an equilibrium polygon with $\frac{M}{EI}$ as a load curve.

The practical application of this theorem is extremely simple and will be fully explained by applying it to the same numerical example which has been considered above in Fig. 23.

19. Fig. 27 gives all the necessary details for the construction of the elastic curve. The scale of the shaft is the same as before: 1 inch represents 100 inches, but for the $\frac{M}{EI}$ curve a smaller scale than before has been chosen, namely 1 inch represents $\frac{6}{100{,}000 \text{ inch}}$. As before, the length of the beam has been divided into twenty equal parts. Through the centre of each strip verticals 1, 2, 3 . . . . 19, 20, have been drawn. According to the

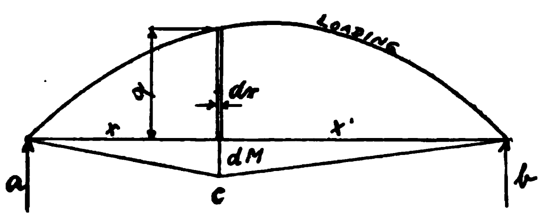


FIG. 26.

theory of equilibrium-polygons, the intercepts between the bottom and top lines of the $\frac{M}{EI}$ polygon (measured on the verticals 1, 2, ... 19, 20) are to be treated as imaginary loads and to be laid off on a load line 0 – 20 (at the left of the figure), so that

0 – 1 = intercept on vertical through strip 1
1 – 2 = " " " " " 2, etc.

The length of this load-line is the reason why a smaller scale was selected for the $\frac{M}{EI}$ polygon.

20. To construct the equilibrium polygon, take any point O' as a pole, draw rays $0 - O'$, $1 - O'$, $2 - O'$, ... $19 - O'$, $20 - O'$. From any point a on the vertical through the left support draw $a - c$ parallel to $0 - O'$, which cuts vertical No. 1 in c; draw $c - d$ parallel to $1 - O'$, which cuts vertical No. 2 in d; draw $d - e$ parallel to $2 - O'$, which cuts vertical No. 3 in e, and so on until the vertical containing the right support is intersected in the point b. Join a to b, then the vertical intercepts between the closing line $a - b$ and the equilibrium polygon are to some scale the ordinates of the

elastic curve. The scale depends upon the horizontal distance H between the pole $\mathcal{O}'$ and the load line $0-20$ (called the "pole-distance"). For practical reasons it is desirable to obtain a polygon whose ordinates are a simple multiple of the actual deformations.

The ordinates of the equilibrium polygon in Fig. 27 are five times

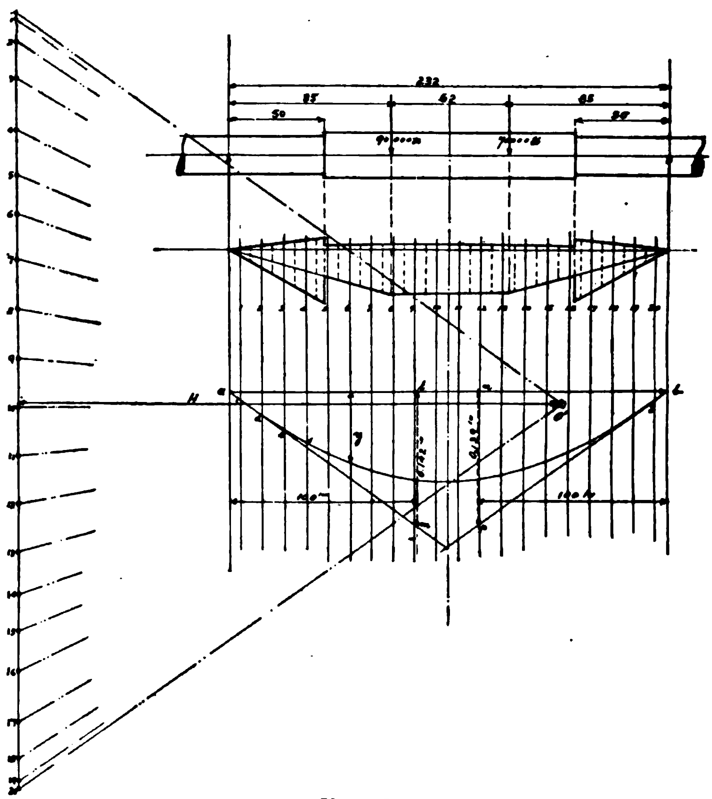


FIG. 27.

full size. The determination of the pole-distance which furnishes this particular scale is the only point about Mohr's method which requires a little brain work. To find H, we may reason as follows: 1 inch of the $\frac{M}{EI}$ polygon represents $\frac{6}{100,000}\,\text{inch}$; the width of each of the twenty strips is $\frac{232}{20}$ inch $= 11.6$ inch; therefore a strip 1 inch high represents $\frac{6 \times 11.6}{100,000} = \frac{6.96}{10,000}$; or, in other words: $\frac{6.96}{10\,000}$ is the scale for the elastic weights. According to the theory of equilibrium polygons, the value of the moment (whether caused by imaginary elastic weights or by actual gravity weights) at any point 6 of the beams is

$M = H$ inch $\times$ scale for distances $\times$ y inch $\times$ scale for weights

in which $H =$ the pole distance and

$y =$ the ordinate of the equilibrium polygon.

21. But, as before proven, the moments caused by the elastic weights equal the ordinates of the elastic curve or deflections δ. Therefore we have H inch $\times$ scale for distances $\times$ y inch $\times$ scale for elastic weights $= \delta$ inch.

Now, our aim is to make $y = 5\,\delta$, hence we obtain

$$H = \frac{1 \text{ inch}}{5 \times \text{scale for dist.} \times \text{scale for elastic weights}};$$

or, in our case $H = \frac{10\,000}{5 \times 100 \times 6.96} = 2.88$ inches, which value has been used in Fig. 27.

As to the vertical position of the pole O', it should be placed opposite the force representing the strip in the centre of the beam, so that the closing line $a-b$ may be approximately horizontal.

NOTE.—Those readers, who are familiar with the theory of graphical statics, will know that, if the pole O' be moved vertically up and down, the shape of the equilibrium polygon and the inclination of its closing line $a - b$ are changed, but that the magnitude of its ordinates is not affected.

If it should be required to have the closing line exactly horizontal, the ordinates y found in Fig. 27 may be laid off from a horizontal axis, which is much easier and more convenient than the scientific method of determining the correct vertical position of the pole O'.

22. To find the directions of the tangents to the elastic curve at the end sections of the beam, we proceed as follows: Prolong the first and the last segments $a-c$ and $g-b$ of the equilibrium polygon (remember that $a-c$ is parallel to ray $0-O'$ and $g-b$ is parallel to ray $20-O'$), draw verticals $l-m$ and $n-p$ 100 inches distant from the verticals through a and b respectively; measure lm and np in the scale of the ordinates of the elastic curve, then $\tau_a = \frac{lm}{100}$ and $\tau_b = \frac{np}{100}$. In our example we find $lm = 0.142$ inch and $np = 0.139$ inch, which gives the angles

$$\tau_a = \frac{0.142}{100} = \frac{1.42}{1000} \text{ and}$$

$$\tau_b = \frac{0.139}{100} = \frac{1.39}{1000}.$$

23. Comparing these figures with those which were found by the double integration method, we see that the former exceed the latter by about 3 per cent. As neither method is entirely free from small inaccuracies, it is impossible to say which of the two is nearer to the truth; but for all practical purposes a difference of only 3 per cent. is immaterial, because our assumptions and constants include more serious errors than that. The greatest deflec-

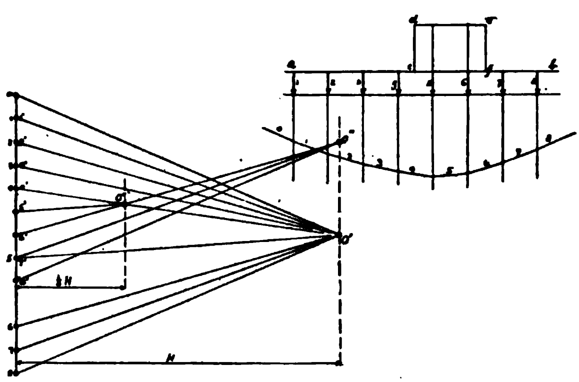


FIG. 28.

tion is 0.95 inch as found by Mohr's method against 0.94 inch as found by the double integration method.

There can be no doubt that the graphical (Mohr's) method is much simpler than the semi-graphical method (double integration with a planimetre). But nevertheless it does not yet represent the highest degree of simplicity. Mr. Vianello, an Italian engineer, has done away with the labor of distorting the polygon of bending moments in the inverse ratio of the moments of inertia. Instead he varies the distance between the pole and the load line in the direct ratio of the moment of inertia. A simple reasoning will prove the correctness of his method.

24. In Fig. 28 let $a - b$ be a part of the M-polygon for some beam. For simplicity M is assumed constant. Let I_0 be the moment of inertia of the beam from a to c and from f to b; let $\frac{1}{2} I_0$ be the moment of inertia for the portion between c and f. According

to the rules given above for Mohr's method, the ordinates between c and f have to be multiplied by three, which gives the M'-polygon (or, to another scale, the $\frac{M}{EI}$-polygon) $a-c-d-e-f-b$. The ordinates 1, 2, 3, etc. are laid off on a load line $0-8$, as indicated by the figures at the left of said line. The polar diagram with pole O' and the corresponding equilibrium polygon are drawn. The figures at the right of the load line denote the ordinates of the straight line $a-b$, that is of the original M-polygon (or $\frac{M}{EI_0}$-polygon). Ordinate $5'$ is only one-third of ordinate 5, and it is evident that the segment 5 of the equilibrium polygon will not be affected by the shortening of the ordinate, if we find a new pole O'', so that $5'-O''$ will be parallel to $5-O'$. Obviously O'' must lie on ray $4-O'$. If $4-O''$ be made equal to one-third of $4-O'$, it follows from the similarity of the triangles $O''45'$ and $O'45$, that $5'-O''$ is parallel to $5-O'$. Similarly $6'-O''$ is parallel to $6-O'$. Here the moment of inertia assumes the original value I_0, hence the rest of the equilibrium polygon has to be drawn with the original pole distance H. Prolong $6'-O''$ to the intersection O''' with the vertical through pole O'; then $7'-O'''$ will be parallel to $7-O'$ and $8'-O'''$ parallel to $8-O'$.

25. But as the shape of the equilibrium polygon depends merely upon the direction of the rays in the polar diagram, the two methods give the same result, and the truth of Vianello's theorem is proven.

From the foregoing we derive the following rule for the construction of the elastic curve: Draw the polygon of bending moments and divide it into a sufficient number of strips. Consider each strip as an imaginary load, draw an equilibrium polygon for these loads and vary the pole distance in the direct ratio of the moments of inertia.

26. Fig. 29 is an application of this principle to the same shaft which has served to illustrate the other methods. The distribution of loads and the assumption with regard to the moments of inertia coincide with those of Fig. 24 and need not be repeated. The curve under the sketch of the shaft is the polygon of bending moments, divided by EI_0, where $I_0 =$ moment of inertia at centre of shaft. The $\frac{M}{EI_0}$ curve presents the smooth appearance which is usual with curves of bending moments, in contradistinction to

the ragged outline of the $\frac{M}{EI}$ curves in Figs. 23, 24, and 27. The variations in the cross section of the shaft are taken care of by corresponding variations of the pole distance. As Fig. 29 contains

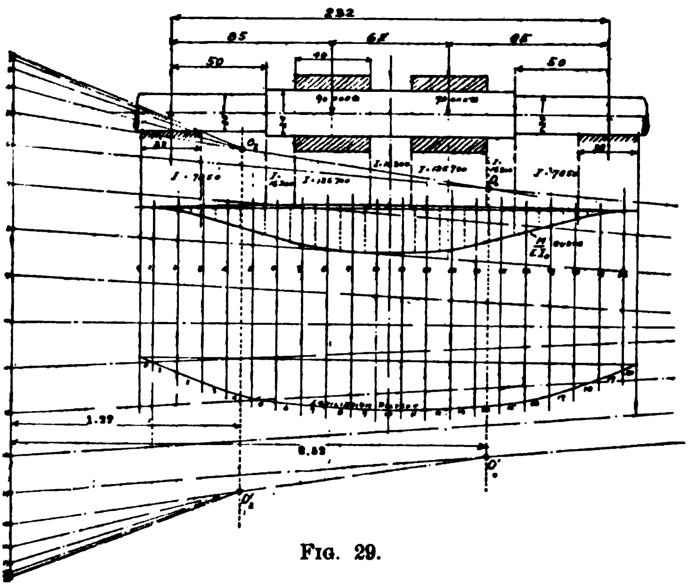


FIG. 29.

many lines and is not so lucid as the previous illustrations, a detailed description of the construction will be given.

27. Scale for distances 100 (*i.e.*, 1 inch represents 100 inches) length of beam between outside of bearings 264 inches; width of each strip $\frac{264}{20} = 13.2$ inches; 1 inch of $\frac{M}{EI_o}$ curve represents $\frac{6}{100,000 \text{ inch}}$. Hence a strip 1 inch high represents $\frac{6 \times 13.2 \text{ inches}}{100,000 \text{ inches}}$ $= \frac{7.92}{10,000}$, which is the scale for the "elastic weights."

Ratio $\frac{\text{ordinates of equilibrium polygon}}{\text{ordinates of elastic curve}} = 5$, therefore pole distance for $I_o = 16,300$.

$$H_o = \frac{10,000}{5 \times 100 \times 7.92} = 2.54 \text{ inches. Further,}$$

$$H_1 (\text{for } I_1 = 125,700) = \frac{2.54 \times 125,700}{16300} = \text{about } 19.5 \text{ inches}$$

$$\text{and } H_2 (\text{for } I_2 = \quad 7850) = \frac{5.05 \times 7850}{16,300} \quad = 1.22 \text{ inches.}$$

28. In order to obtain the closing line approximately horizontal it is advantageous to begin the equilibrium polygon near the centre and to work both ways, that is to the right and to the left. The moment of inertia at the centre is $I_o = 16{,}300$; this seems to call for a pole-distance of $H_o = 2.54$ inches. But, as I_o extends only over $\frac{4}{5}$ of the width of the strips 10 and 11, the pole distance must be increased to $H_o + \frac{1}{5}(H_1 - H_o)$ which gives about 5 inches. With this distance locate O' opposite the lower end of load 10_1 (unfortunately O' falls outside of the limits of the illustration), draw rays $9 - O'$, $10 - O'$, $11 - O'$, and the segments 9, 10, and 11, respectively parallel to these rays. Prolong rays $9 - O'$ and $11 - O'$ to the intersections O_1 and O_1' with a vertical 19.5 inches distant from the load line, draw rays $O_1 - 8$, $O_1 - 7$, $O_1 - 6$, and segments 8, 7, 6 respectively parallel to them. Similarly draw rays $O_1' - 12$, $O_1' - 13$, $O_1' - 14$, and segments 12, 13, 14 respectively parallel to them. The intersections of rays $O_1' - 6$ and $O_1' - 14$ with a vertical 2.52 inches distant from the load line locate two poles O_o and O_o'; draw rays $O_o - 5$ and $O_o' - 15$, and segments 5 and 15 parallel to these rays. A vertical 1.22 inches distant from the load line is cut by the rays in O_2 and in O_2', from which points draw rays to the rest of the points on the load line. Segments 4, 3, 2, 1, 0, and 16, 17, 18, 19, 20, parallel to their corresponding rays and the closing line complete the equilibrium polygon. The latter comes very close to the curve which was obtained in Fig. 24 and calls for no further remarks.

29. The method which has just been treated and which might be termed "the multipolar method," is the simplest and the most rapid for draughtsmen, whose occupation requires frequent constructions of deflection curves; but it must not be overlooked that men who have to deal with the deformations of beams and shafts only occasionally are apt to lose their way among the great number of poles and to make serious mistakes. In this case either of the two other given methods is preferable.

30. There exist several graphical methods of integration besides those which have been discussed in the present article, but as they are comparatively unimportant for practical use, they will not be explained here. While the graphical computation is particularly well fit for the investigation of shafts, it is by no means restricted to such, but is almost equally well suited for any other kind of beam which is either supported at the two extremities or fixed (built *in*) at one end and free at the other. For beams of variable

cross section which are rigidly fixed at either end, the purely analytical calculation fails altogether and the graphical methods offer the only possible means for the solution of problems (even with regard to strength alone). But, while for beams with free ends the deflection curve for the moments of the external forces coincides with the actual deformations, such is not the case for beams whose ends are fixed. Here additional deflection curves for the moments which are brought into play by the fixing of the ends have to be drawn and to be combined with the deflection curve for the applied loads. The application of these theorems is extremely interesting, but it cannot very well be treated here, because it leads too deeply into the theory of mechanics and would take too much space.

No. 958.*

FINER SCREW THREADS.†

BY CHARLES T. PORTER, MONTCLAIR, N. J.
(Honorary Member of the Society.)

1. I HAVE for several years felt a growing conviction that the pitches of our machine screw threads are far too coarse, and ought to be changed. They reduce the area of the bolt unnecessarily. The Sellers thread made a considerable gain in this respect, but in the larger bolts the reduction of area is still two or three times as much as it needs to be. Again, the inclination of the thread permits the nut to be jarred loose easily. For these two reasons, threads of much finer pitch seem to be called for. Finer threads will also be stronger to resist stripping, the circle on which the shear must take place being larger. This, however, is of no practical consequence, as the strength of threads to resist stripping in nuts of standard height is now more than twice the strength of the bolt.

2. The gain in strength of the bolt by the use of finer threads is shown in detail in the following table, and the reduction of the inclination is illustrated in the diagrams. The system there represented is one that I have contemplated for my own use. Other engineers may think it will be useful for them also.

It will be observed that fractions and odd numbers are avoided, and that the coarsest thread is six to the inch. Sharp angles at the bottom of threads—even the obtuse angles of 120 degrees in the Sellers thread—invite fracture, especially in steel. A very small arc, preserving continuity of surface, will remedy this defect. In this system the angles will be rounded and filleted to the radius of .0045 inch.

---

* Presented at the New York meeting (December, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions.*

† For further references on the same topic consult *Transactions* as follows:
No. 9, vol. i., p. 123: "Standard Sizes of Screw Threads." G. R. Stetson.
No. 944, vol. xxiii., p. 603: "Proposed Standard for Machine Screw Thread Sizes." C. C. Tyler.

The accompanying outline (Fig. 30) represents the finest thread, twenty-four to the inch, magnified fifty times. This arc, of .0045 inch radius, it will be seen, rounds this thread completely. The bottom of the coarsest thread, six to the inch, is also represented, on the same scale, in a dotted line. It shows the efficiency of this arc to avoid the breaking angle in all threads. This last feature I shall apply also to pipe threads.

3. It will be observed that in the bolts most commonly used the increase of strength averages about 20 per cent., and that in all the bolts above 2½ inches the strength of each bolt, threaded

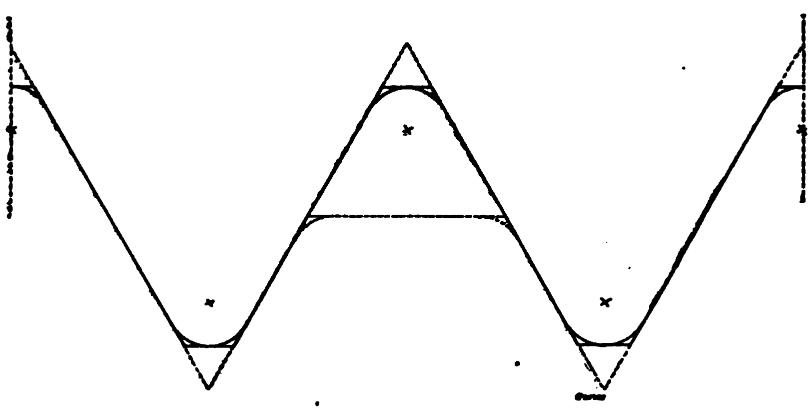


FIG. 30.

on the system here proposed, will equal or exceed the strength of the next larger bolt, threaded on the existing system.

4. The reduction of inclination effected by the proposed system will be best shown by the graphical method. For this purpose I have selected the 1-inch bolt. If a right-angled triangle be drawn, the base of which is equal to the circumference of the top or of the bottom of the thread, and the height equals the pitch, the hypotenuse will represent the inclination of the thread and its length in one revolution.

But these angles are too small for distinct illustration. I have, therefore, drawn the following diagrams, Figs. 31 and 32, to two scales. The horizontal scale is full size. The vertical scale is ten times full size. In these the relation of the inclinations to each other can be accurately observed. It will be seen that while the reduction of the inclination at the top of the thread in this bolt is 50 per cent., its reduction at the bottom of the thread is

TABLE I.

Number of Threads to the Inch.		Diameters.			Areas.			Increase of Area.	
		Of Bolt.	At Bottom of Thread.		Of Bolt.	At Bottom of Thread.			
Present.	Pro-posed.	Inches.	Present. Inches.	Pro-posed. Inches.	Square Inches.	Present. Sq. Ins.	Pro-posed. Sq. Ins.	Square Inches.	Per cent.
20	24	¼	.185	.1958	.04908	.027	.03	.003	11.11
18	24	5/16	.240	.2563	.07669	.045	.0525	.0075	16.66
16	23	⅜	.294	.3160	.1104	.068	.0785	.0105	15.44
14	22	7/16	.344	.3785	.1503	.093	.1125	.0195	20.96
13	20	½	.400	.435	.1963	.126	.1488	.0228	18.09
12	20	9/16	.454	.4975	.2485	.162	.1943	.0323	20.
11	18	⅝	.507	.5525	.3067	.202	.240	.038	18.81
10	18	¾	.620	.6775	.4417	.302	.361	.059	19.53
9	16	⅞	.731	.794	.6013	.420	.495	.075	18.
8	16	1	.837	.919	.7854	.550	.663	.113	20.54
7	14	1⅛	.940	1.0315	.9940	.695	.837	.142	20.43
7	14	1¼	1.065	1.1565	1.227	.895	1.051	.156	17.43
6	14	1⅜	1.160	1.2815	1.484	1.06	1.289	.229	21.6
6	14	1½	1.284	1.4065	1.767	1.297	1.555	.258	19.89
5½	12	1⅝	1.389	1.5165	2.073	1.518	1.808	.290	19.1
5	12	1¾	1.490	1.6415	2.405	1.743	2.115	.372	21.34
5	12	1⅞	1.615	1.7665	2.761	2.05	2.45	.400	19.51
4½	12	2	1.712	1.8915	3.141	2.305	2.81	.505	21.9
4½	10	2¼	1.962	2.12	3.976	3.025	3.53	.50	16.69
4	10	2½	2.175	2.37	4.908	3.720	4.41	.69	18.54
4	10	2¾	2.425	2.62	5.939	4.62	5.38	.76	16.45
3½	10	3	2.628	2.87	7.068	5.43	6.47	1.04	19.15
3½	10	3¼	2.878	3.12	8 295	6.52	7.65	1.13	17.33
3¼	8	3½	3.100	3.337	9.621	7.55	8.75	1.20	15.89
3	8	3¾	3 317	3.587	11.044	8.65	10.10	1.45	16.76
3	8	4	3.566	3.837	12.566	10.00	11.58	1.58	15.8
2⅞	8	4¼	3.798	4.087	14.186	11.33	13.13	1.80	15.88
2¾	8	4½	4.027	4.337	15.904	12.75	14.80	2.05	16.07
2⅝	6	4¾	4.255	4.534	17.720	14.20	16.15	1.95	13.73
2½	6	5	4.480	4.784	19.635	15.78	18.00	2.22	14.06
2½	6	5¼	4.730	5.034	21.647	17.52	19.90	2.38	13.58
2⅜	6	5½	4.953	5.284	23.758	19.28	21 90	2.62	13.58
2⅜	6	5¾	5.203	5.534	25.967	21.25	24.05	2.80	13.13
2¼	6	6	5.423	5.784	28.274	23.10	26.3	3.20	13.85

considerably more than 50 per cent. Any one who is so inclined can compute *these* inclinations in each of the thirty-four bolts.

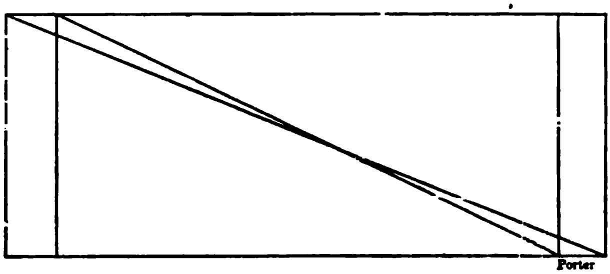


FIG. 31.

The above illustration seems sufficient for the purpose of my argument.

5. In conclusion, I take pleasure in acknowledging my obliga-

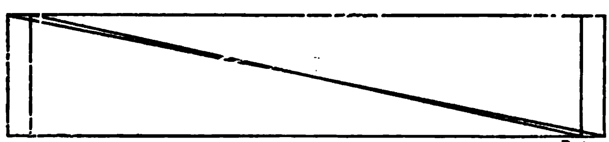


FIG. 32.

tion to Mr. H. F. J. Porter for valuable aid in the preparation of this paper; especially for the suggestion to round the angles of the threads. The increasing use of steel as the material for bolts renders this feature one of special importance.

DISCUSSION.

Mr. Charles T. Porter.—I have one word to say. Mr. John D. Gill kindly sent me a paper read by him before the Franklin Institute in November, 1887, on the subject of changing screw threads, and I find this sentence in that paper, which I would like to bring to the notice of the Society: "Fine threads have frequently been suggested, and your committee in 1864"—that is the committee of the Franklin Institute—"gave some consideration to the question, but the many objections urged against fine threads induced the committee to reject it." I have never been able to learn what those objections were, and I hope that the discussion may bring them out, if there are any real objections to these threads which I have proposed in this paper.

Mr. Fred J. Miller.—I understand that when the present standard of threads was adopted by the Franklin Institute the question of wear was considered, and I believe it has been found in using threads that a fine thread screw which must be frequently removed and inserted and tightened up will wear much faster than one with a coarser thread, and I think that was considered in determining the pitch of the threads selected at that time. That is perhaps a partial answer, at least, to Mr. Porter's request for information as to the way the coarser threads were chosen. They had to consider all possible points, and they chose a standard based, I believe, on what they found to be the practice of the machine shops of the country; they then adopted a compromise between all the various considerations. It is well known that the present screw threads are too coarse for steel screws, especially those which are put in place and remain there, but it is questionable whether they are too coarse for those screws or nuts which must be frequently removed and replaced, and which may fail eventually by wear.

Mr. Gus C. Henning.—Another objection which was offered at that time was this—that the dies and taps wear off just as fast for finer threads as they do for coarser ones. This identical wear of taps and dies will be relatively larger in the finer than in the coarser threads, but I do not think that that will affect the accuracy of threads for the larger sizes. Of course in the smaller threads, from quarter-inch down, that difference in wear would affect the fit between nuts and bolts, and it would make a very appreciable amount, and the result would be that taps and dies would have to be replaced much quicker. That was considered at the time as another objection to introducing finer threads than have been proposed by the Franklin Institute.

*Mr. Porter.**—I will state what occurs to me in respect to this subject of wear, that if we take an inch bolt, for example, 16 threads instead of 8, the wear on those 16 threads should not be any greater than the wear on 16 threads to an inch in a bolt $\frac{3}{8}$ of an inch diameter on which they are now used, and that has never been noticed—that wear—that I know of; and if that is the only objection I think that falls to the ground. On the smaller

* Author's closure, under the Rules.

bolts the threads are not materially changed. That is my answer to the suggestion in respect to wear. I should say that on the point of rounding the angle of the thread, the importance of that has grown upon us, and I have put this sentence at the end of the paper: "The increasing use of steel as the material for bolts renders this feature"—rounding the angles of threads —"one of special importance." I understand that steel bolts break in the most unexpected manner on account of the square angle.

No. 959.*

A NEW OIL-TESTING MACHINE AND SOME OF ITS RESULTS.†

BY ALBERT KINGSBURY, WORCESTER, MASS.
(Member of the Society.)

1. It has become well recognized by experimenters that there are two important properties of lubricating oils and greases on which their value depends—viscosity and body. Viscosity is the property by virtue of which the lubricants form comparatively thick films between rubbing surfaces, permitting perfect lubrication, a property which is well understood and capable of precise measurement. Thurston early pointed out the case of perfect lubrication as probably capable of exact mathematical treatment,‡ and Reynolds, in 1886, published an elaborate analysis of such a case,§ with application to the experiments of Beauchamp Tower.‖

2. As the result of computations from Tower's data, Reynolds found that the minimum thickness of the oil film and the difference of the radii of the brass and the journal were .000375 and .00077 inch respectively, the load being 100 pounds per square inch and the diameter of the journal 4 inches. In 1899 the writer experimented with a journal 3.82 inches in diameter and 10 inches long, bearings and journal having exactly the same radius. The chords

---

* Presented at the New York meeting (December, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

† For further references on the same topic see *Transactions* as follows:

No. 7, vol. i., p. 73: "Measurement of the Friction of Lubricating Oils." C. J. H. Woodbury.

No. 120, vol. iv., p. 315: "Economy in Lubrication of Machinery." Geo. N. Comly.

No. 163, vol. vi., p. 136: "Measurements of Friction of Lubricating Oils." C. J. H. Woodbury.

No. 173, vol. vi., p. 437: "Valuation of Lubricants by Consumers." R. H. Thurston.

No. 404, vol. xi., p. 1013: "Durability of Lubricants." J. E. Denton.

No. 483, vol. xii., p. 405: "Special Experiments with Lubricants." J. E. Denton.

‡ "Friction and Lost Work." Wiley & Sons.

§ "Theory of Lubrication." *Phil. Trans.*, 1886.

‖ *Proceedings of the Inst. Mechanical Engineers*, 1884.

of the bearing surfaces were 3 inches each, the speed 80 and 190 revolutions per minute, and the journal was flooded with machinery oil. By measurement of the displacement of the bearings the oil film was found to have a mean thickness of from .00021 to .00023 inch under loads varying from 27 to 270 pounds per square inch.

3. A condition essential to the formation of such films, as shown by Reynolds, is that the rubbing surfaces should have a very slight inclination to each other in the direction of their relative motion. This condition is generally fulfilled by a slight difference in the radii of the journal and the bearing, due to the original looseness of fitting or to wear. When the loads are very great or the surfaces irregular, or when the conditions are otherwise such as to make the necessary inclination impossible, it is well known that the action of the lubricant is imperfect and frequently very defective. In such cases the theory of Reynolds, which so clearly accords with experiment for the conditions of perfect lubrication, becomes quite inapplicable; nor has any theory been formed which applies to these imperfect or extreme conditions. Such cases occur in pivots, where the surfaces are necessarily parallel, in cylindrical bearings which are too closely fitted, in any portion of any bearing surface where the pressure is unduly high, and in heavily loaded bearings generally. Under any of these circumstances the effect of the lubricant in reducing friction depends mainly upon the "body" or "oiliness." The nature of this property, or combination of properties, is not well understood, but it appears probable that it is an intensified viscosity in that part of the fluid within the region of attraction of the surface molecules of the metal.

4. One of the most frequent causes of contradictory results in friction tests is that the effects of viscosity may readily mask the effects of body, and another cause is found in the changes in the rubbing surfaces which always take place with wear, and which must, therefore, accompany any test for body.

In any well-fitted journal in which perfect lubrication exists, the friction is determined by the speed, the pressure, and the viscosity of the oil. Varying any one of these factors while keeping the others constant, there is some value of the variable for which the coefficient of friction is a minimum * and which at the

* Thurston: "Friction and Lost Work," pp. 311, 326. Woodbury: "Measurement of Friction of Lubricating Oils," *Transactions* A. S. M. E., vol. vi., p. 151.

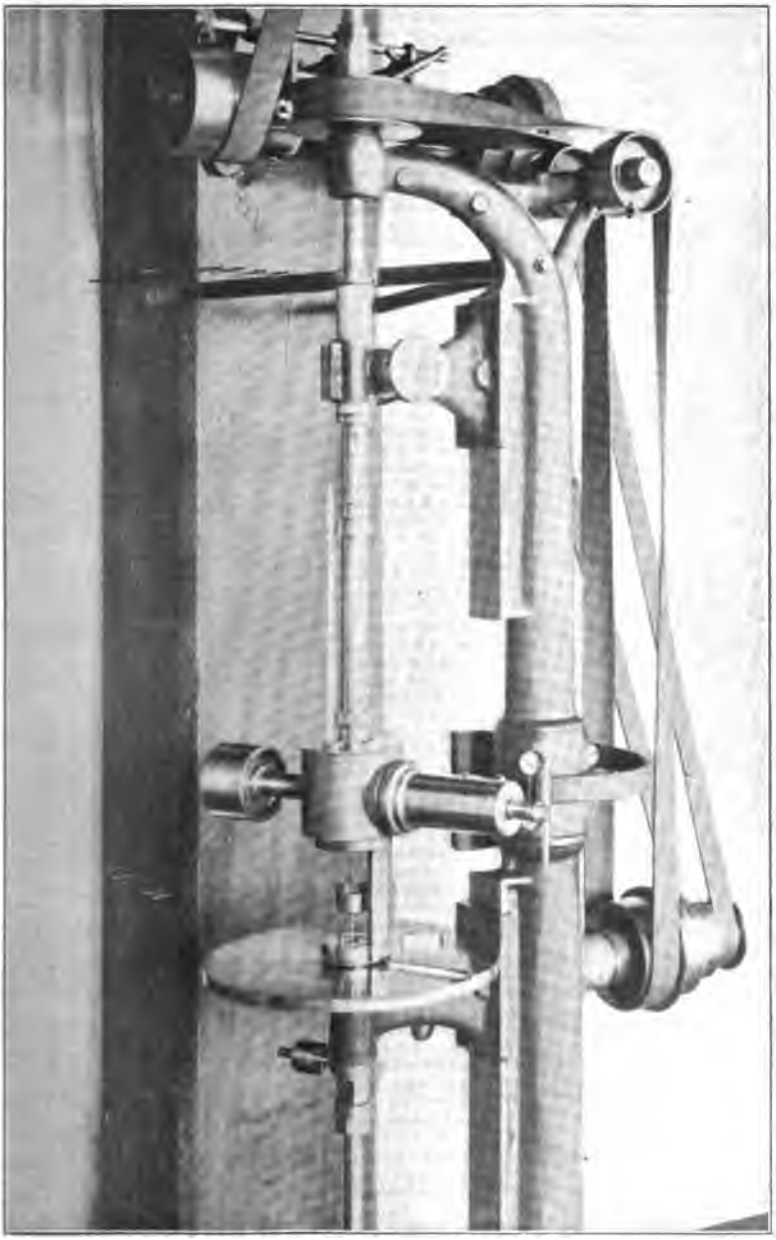


Fig. 33.

same time marks very nearly the limit of the variable for the condition of perfect lubrication. This is illustrated by the curves plotted in Fig. 34, representing tests made on the machine described later. In these tests the load and the speed were kept constant, the viscosity of the oil being varied in each case by varying the temperature. For each of the three oils, the minimum coefficient of friction is reached at a temperature of about 180 degrees Fahr., with the given speed and pressure. As the

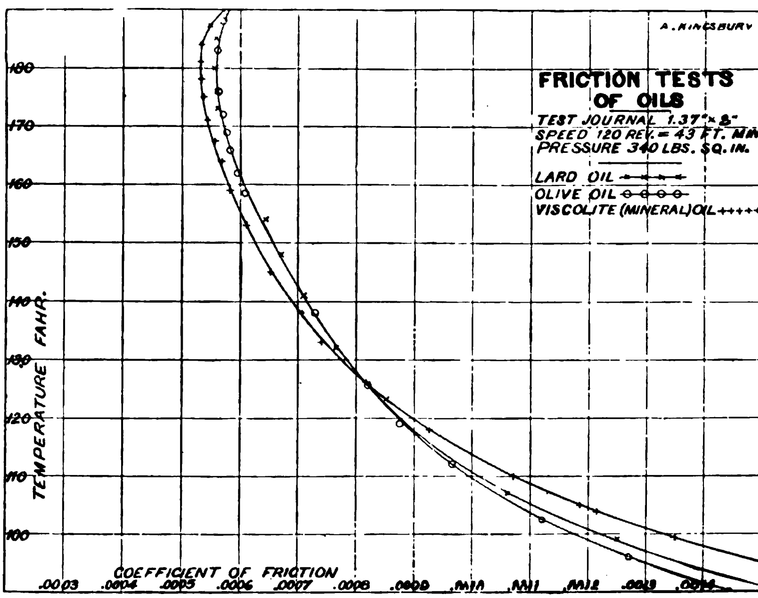


FIG. 34.

temperature varies either way from this value, the coefficient of friction increases; on the one hand increasing with the viscosity of the oil, the metallic surfaces being completely separated by a measurably thick film; on the other hand increasing because the decreased viscosity permits the surfaces to approach so that some parts of the nominal bearing areas are subjected to very intense pressures, up to the limits of strength or plasticity of the metals. It is in these localities that the body of the lubricant determines to some extent the friction and the wear of the journal, the viscosity being also effective on some parts of the area.

5. The relations of the coefficient of friction to the other variables, in a journal giving results as plotted in Fig. 34, may be stated as follows:

With increase of	Where the viscosity is effective, the coefficient of friction	Where the body is effective, the coefficient of friction
Pressure.............	Decreases.	Increases.
Speed................	Increases.	Decreases.
Temperature.........	Decreases.	Increases.
Viscosity.............	Increases.	Decreases.
Body................	....	Decreases.

It is thus seen that the effects of body and of viscosity are in nearly all respects diametrically opposite, and that it must necessarily be very difficult to derive reliable information regarding the lubricating values of oils from friction tests in which the effects of viscosity and those of body are not separately recognizable. Under this consideration, methods of testing which are described in this paper are arranged with special reference to the conditions under which the effects of either property may be investigated independently of the effects of the other. The apparatus used is serviceable also for tests under any intermediate condition.

6. Fig. 33 shows the general appearance of the testing machine, for the frame and driving parts of which a 14-inch drilling machine was utilized. The test journal has its axis vertical; it is suspended from the spindle by means of a flexible coupling and runs between two opposed bearings in a cylindrical cup or case, which may be filled with the oil to be tested if a "bath" is desired. The load on the bearings is provided by means of a helical spring of 900 pounds capacity, with screw adjustment and with a device for quick application or removal of the load without disturbing the adjustment. This spring is enclosed in a horizontal tube attached to the side of the oil case. The cup has a cover with a small hole for the insertion of a thermometer.

7. The cup and attached parts are borne on a hollow vertical spindle 1⅜ inches in diameter, turning freely in a sleeve supported from the frame of the machine; the spindle extends about two feet below the sleeve and is suspended from a fixed bracket by a tempered steel wire passing through the spindle to its lower end. In testing, these suspended parts turn freely to a position where the torsion of the suspension wire balances the friction at the test journal, and the angle of torsion, which may be as great as 270 degrees, is read from a graduated disk. The suspended parts being counterbalanced, there is no appreciable pressure of the spindle against its sleeve; and when the oil in this bearing becomes evenly distributed, there is no error from friction, as has been

amply proven by tests with an "optical lever" as well as by the uniformity of the results in use. At the same time, the viscosity of the oil serves the purpose of damping the oscillations which arise from variations in speed or friction at the test journal. This mode of suspension gives large indications for very small frictions at the test journal, while a helical spring placed on the extension of the spindle is added for tests involving great friction.

8. The cup and the test journal contained in it may be heated as desired by a Bunsen flame. The revolutions of the journal are indicated by a counting device, not shown in the figure.

9. For tests involving perfect lubrication (friction due to viscosity only), the test journal used is $1\frac{3}{8}$ inches diameter, of tool steel, hardened, ground, and polished. The brasses are sectors cut from a ring finished in the lathe, each having an arc of about 120 degrees and a length of 2 inches. These brasses are fitted with some care, so that when perfectly clean they may be made to adhere to the journal after the manner of well-fitted "surface plates." In making tests, care is taken to prevent wear of these parts, which are used only under such loads that the oil film effects complete separation of the surfaces and entirely prevents wear; the load is always relieved before starting or stopping the journal; and, finally, a friction device in the driving coupling safeguards the journal from motion against excessive friction. These precautions against wear are necessary to insure the constancy of results.

10. It will be noted that the above conditions are not such as occur in practice; but it should also be noted that this method of testing is intended to show the effects of viscosity in lubricants and not the varying imperfection of any particular bearing surfaces subjected to wear.

11. In Figs. 34 to 37 are shown curves plotted from tests made with the test journal and bearings just described, a bath of oil being used in each instance. Figs. 34, 36, and 37 show the effects of variation in viscosity upon the friction, both by the use of oils of different viscosities and by the variation in viscosity due to change of temperature. In Fig. 34, the lard oil and the olive oil have very nearly the same viscosity, the lard oil being slightly more viscous, as is also and more clearly shown in Fig. 35; the mineral oil (Fig. 34) is more viscous than either at low temperatures, but less at high temperatures (see also Fig. 38). Fig. 36 shows the friction of four cylinder oils with varying temperatures;

Fig. 37, four engine oils. Fig. 38 shows relations of friction, speed, and viscosity for five oils at three different speeds; the viscosity was found by the ordinary and rather crude pipette method. These curves, although relating to conditions not far removed from the limit of capacity of the journal, approximately verify Reynolds' deduction that the friction is proportional to the viscosity of the oil, and they also show the friction to vary roughly as the square root of the speed. The data for Fig. 38 were taken from average results of tests made in the laboratory of the Worcester Poly-

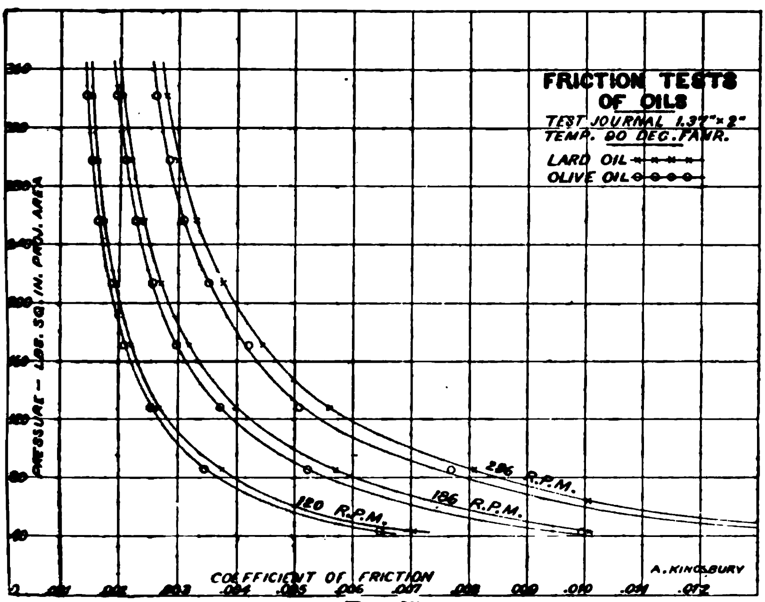


FIG. 35.

technic Institute, by members of the class of 1901; the degree of certainty attained in the friction tests may be illustrated by the following values of the coefficient of friction found by the successive experimenters, no corrections being made for variations in speed nor for errors in calibration of the torsion wire.

COEFFICIENTS OF FRICTION FOR SPERM OIL; PRESSURE, 340 LBS. SQ. IN. 90° FAHR.

117 R. P. M.	188 R. P. M.	281 R. P. M.
.000906	.001171	.00146
.000915	.001158	.00155
.000886	.001158	.00151
.000915	.001125	

It may be noted that the lowest coefficients of friction shown in Figs. 34, 36, and 37 are extremely small, and the writer believes them to be smaller than any hitherto recorded for lubrication maintained solely by the motion of the journal. The minimum friction is but one-fifth of that of the best ball bearing, as far as

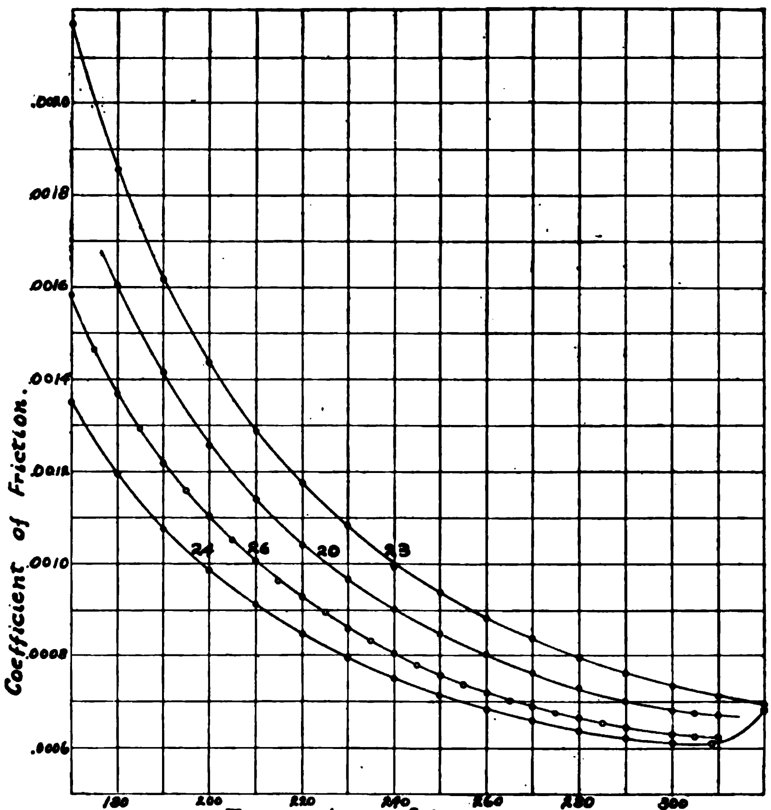


FIG. 36.—FRICTION TESTS OF CYLINDER OILS.
PRESSURE, 340 POUNDS PER SQUARE INCH. SPEED, 94 FEET PER MINUTE.

tests of the latter have been recorded. The value for the minimum coefficient for all oils tested on this journal has been found to be approximately .0006, whatever the speed, pressure, and temperature by which the minimum coefficient may be determined; the oils varying from "spindle" to "cylinder," the speeds from 42 to 101 feet per minute, the pressures up to 340 pounds per square inch and the temperatures up to 340 degrees Fahr. Very nearly the same minimum coefficient was found in the writer's tests * of a journal lubricated by air only; the value in which case was .00075.

12. For tests for comparing oils with respect to body or oiliness,

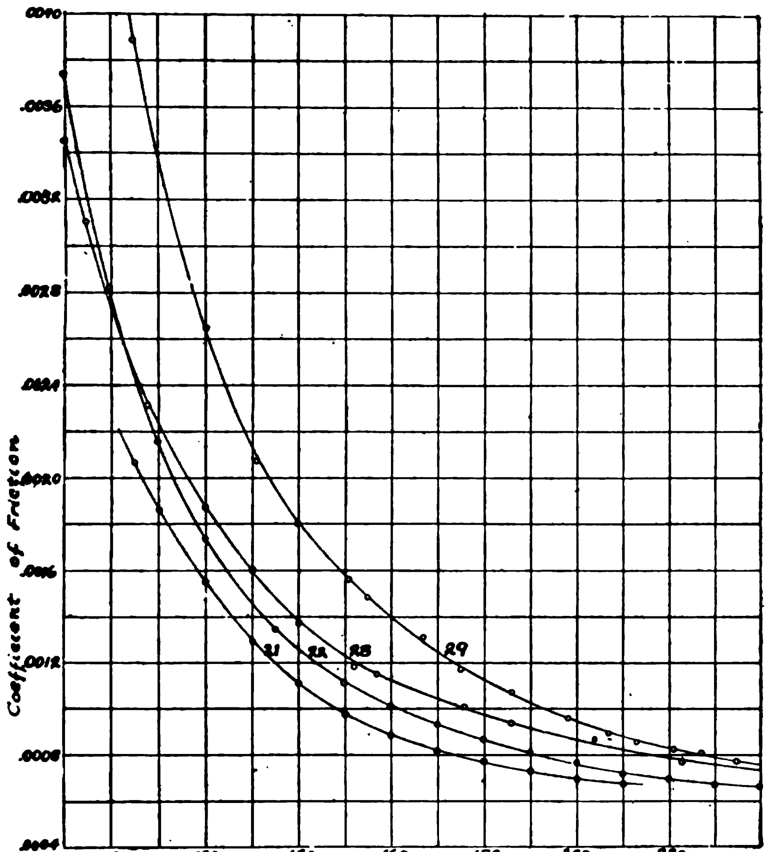


FIG. 37.—FRICTION TESTS OF ENGINE OILS.
PRESSURE, 170 POUNDS PER SQUARE INCH. SPEED, 94 FEET PER MINUTE.

the best results have been obtained by the use of a hardened and polished steel journal $\frac{1}{4}$ inch in diameter, running between two brass bearings about 1 inch long; on this small journal pressures up to 8,000 pounds per square inch may be applied if necessary. The samples of oil to be compared are contained in small brass

* *Journal of the American Society Naval Engineers*, 1897.

cups placed inside the case and surrounding the test journal, each cup having a wire for transferring oil to the journal; the case, samples, and journal are together heated to any desired temperature.

13. In testing for body, the oils are compared in pairs, being applied alternately at the upper end of the bearing; one being applied until the friction becomes constant or nearly so, the other is then applied until it displaces the first, and again the friction becomes constant at the new value; this process is repeated several times. The oil giving the less friction is assumed to have the greater body. In this way the order of the body values of six samples of oils of the same class may generally be determined for any given temperature in an hour or less; the friction indications rapidly follow the changes of the oils and are generally quite consistent. When the oils to be compared are of different classes (as mineral oils with fixed oils), the first friction indications on changing oils are frequently misleading, and a longer time is required to insure certainty of results.

14. The speeds for the body tests are made rather low and pressures not unnecessarily high, in order to avoid heating and wear of the journal, since it is essential for comparative purposes that the surfaces should be in the same condition for both samples compared —a requisite which above all others led to the development of this method of testing. Again, the actual temperature of the oil at the test surfaces is shown more nearly by the thermometer if but little heating by friction be permitted. The writer has not found the order of body values, as determined by this method, to vary with the speed or the pressure within a considerable range. A speed of 50 to 100 revolutions (3 to 6 feet per minute), with sufficient pressure to make the coefficient of friction only as great as .01 to .03, have been found most satisfactory; the pressures being from 500 to 5,000 pounds per square inch, according to the character of the oils.

15. The results of this method of testing for body agree thoroughly with the principal fact hitherto established with regard to body as distinguished from viscosity—namely, that the mineral oils as a class have much less body than the animal and vegetable oils. For example, in a body test of mineral oil and lard oil having viscosities 98.9 and 83.7 respectively at 90 degrees F., as determined by the Dudley pipette, the lard oil, although the less viscous, gives very decided evidence of greater body, by its much

smaller friction. On the other hand, certain cylinder oils, wholly or largely mineral, and exceeding lard oil greatly in viscosity have also greater body than lard oil.

16. The method of testing readily indicates differences in body in samples of nominally the same oil from different manufac-

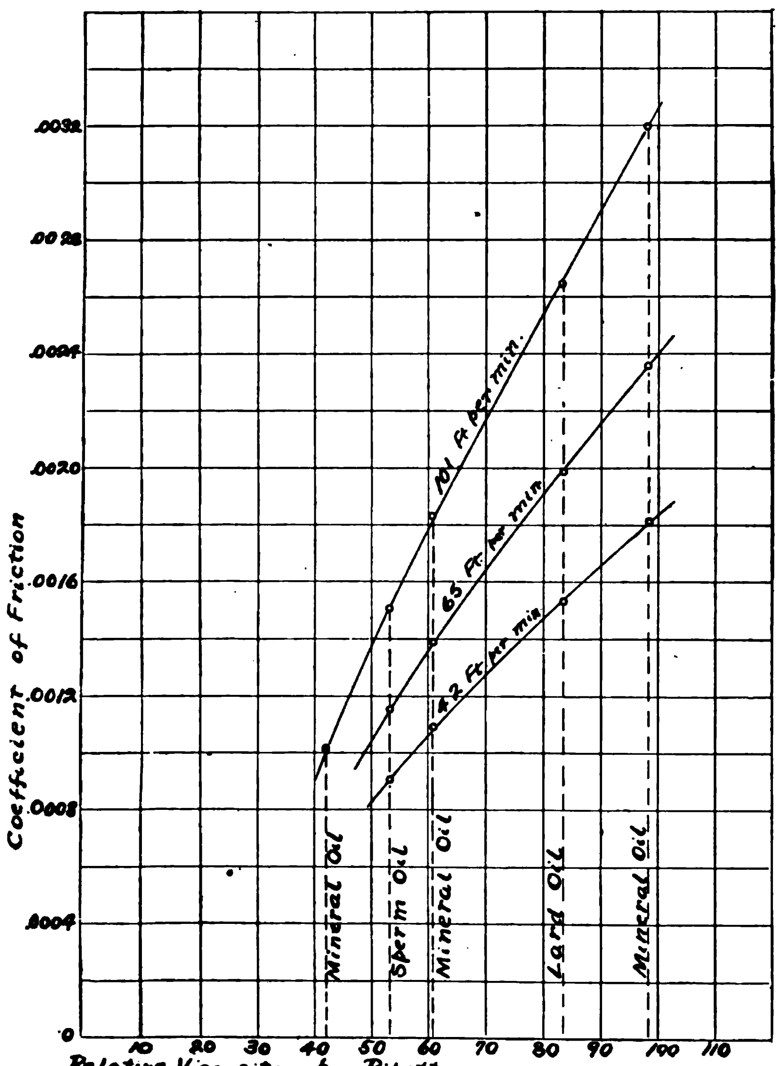


FIG. 38—FRICTION, VISCOSITY, AND SPEED.
PRESSURE, 340 POUNDS PER SQUARE INCH. TEMPERATURE, 90 DEGREES FAHR.

turers, such as lard oil; change of body in a given fixed oil on exposure to the air for some time; the addition of small proportions of mineral oil to animal or to vegetable oil, or vice versa.

17. Among the specific results thus far obtained, the four cylinder oils whose variations of viscosity with temperature are shown in Fig. 36, were found to have body in the same order as viscosity; the body being tested at 180 degrees and 312 degrees Fahr. Similar results were found for the oils in Fig. 37. Again, samples of castor, lard, olive, and sperm oils were placed in the order named by the body test, which order was the same as that of their viscosities. It thus appears that body is in some way related to viscosity, but the relation must be quite different in the mineral oils and the fixed oils.

18. The following tables of observations will serve to show the character of the numerical results of tests made in this way, the oils compared being in the first case two samples of lard oil, and in the second case two engine oils, Nos. 28 and 29 (see Fig. 37 for viscosity tests); speed, 105 revolutions per minute (6.9 feet per minute):

BODY TESTS OF WINTER STRAINED LARD OILS.

Load, 800 lbs.; pressure 2,550. lbs. sq. in.

Oil No.	Torsion, Degrees.	Coefficient of Friction.	Temperature Fahr.
1	33	.0233	72
2	25	.0176	....
1	31	.0218	....
2	24	.0169	....
1	30.5	.0215	....
2	23 5	.0166	....
1	29.5	.0208	....
2	23	.0162	72

BODY TESTS OF ENGINE OILS.

Oil No.	Torsion, Degrees.	Coefficient of Friction.	Temperature Fahr.
	Load, 200 lbs.; pressure, 1,700 lbs. sq. in.		
29	11.5	.0124	69
28	15	.0161	69
29	11	.0118	69
28	15	.0161	69
	Load, 100 lbs.; pressure, 850 lbs. sq. in.		
28	8.5	.0182	120
29	4.0	.0086	120
28	5.0	.0107	120
29	3.5	.0075	120

Thus, while the coefficient of friction is not always constant for any one oil, the one effecting the greater reduction of friction is readily distinguished, and, hence, is to be regarded as having the greater body. This appears to be the principal use which can be made of the numerical results, since the mean values of the coefficients of friction are not characteristic of the oils, but depend also upon the varying degree of roughness of the surfaces, the loads, the speeds, the temperatures, and the kinds of metals forming the journal and the bearing. Nevertheless, great or small differences in the values of the coefficients of friction must be taken as indicating correspondingly great or small differences in body.

DISCUSSION.

Prof. R. H. Thurston.—Professor Kingsbury's paper impresses me as being a very exceptionally valuable contribution to the literature of its subject. The results of his investigation, as illustrated by the diagrams presented, have this very important peculiarity: that they exhibit, as, I think, never has been done before, the laws of variation of frictional resistance when the lubricant is maintained in an invariable state, and in such manner as to show precisely what are the effects upon thoroughly lubricated surfaces, of simple change of temperature and of simple variation of pressure, uncomplicated by variations of condition of the metal surfaces between which the lubricants are placed. These curves are the most complete and the smoothest, on the whole, that I have yet met with, with perhaps the single exception of some of those of Woodbury, representing his experiments on the mineral oils.* These later tests, however, have greater range, and are also, in part, outside the limit of the earlier work. These extraordinarily low coefficients, also would seem to indicate a more perfect attainment of the condition of maximum effectiveness of lubrication—complete separation of the metals, the film of oil being maintained intact throughout. In all earlier experiments, we find evidence of more or less metallic contact and rubbing at some stage of the experiment, converting fluid into solid friction and introducing a change of the law of variation, thus giving curves of correspondingly varying law. Such changes of con-

* "Friction and Lost Work in Machinery and Mill Work," R. H. Thurston, New York, J. Wiley & Sons; London, Chapman & Hall.

dition may be found illustrated in ample extent and variety in work published by me when pioneering in this field.*

The point of minimum friction, to which I then called attention, is better exhibited in Fig. 34 of the paper than in any of my curves; while the latter seem to indicate that this critical temperature of maximum effectiveness of the lubricant is approximated in a variety of oils, organic as well as inorganic. But it is to be noted that journals in ordinary work do not usually attain that temperature and that the difference among the oils increase as the temperature is lower, at least within the allowable range.† The minimum coefficient reported in these experiments is the lowest with which I have met, and may perhaps be accepted as that to which perfect lubrication approximates as the condition of the journal and the system of lubrication approximates perfection.

The very closely hyperbolic form of these curves is another very interesting result of this work. It follows that, since the product of the coefficient of friction and the pressure is, under such circumstances, practically constant, the total frictional resistance, under similarly perfect conditions, is unaffected by change of load on the journal. This is one of those phenomena which conspire to make the friction of the steam engine constant for all loads, as I showed by direct experiment many years ago, in the case, particularly, of the non-condensing engine.‡

Professor Kingsbury's oil-testing machine is a very ingenious and remarkably refined piece of scientific apparatus, and seems especially suited to such peculiarly fine work of investigation as is here illustrated. The difficulties of determining the effect of varying temperature in this case can only be fully understood by those who have attempted such researches, and they seem to be, by this apparatus, admirably disposed of. It brings out, as never was done before, the differences between "viscosity" and what its inventor calls "body," a quality which remains to be defined.

In illustration of the correspondences and the differences between the work of which the paper is descriptive, and that which is ordinarily performed by the standard methods and ordinarily satisfactory apparatus of the laboratory in commercial investiga-

* Ibidem. † Ibidem.

‡ "Manual of the Steam Engine," vol. ii., chap. v., §§ 182–186.

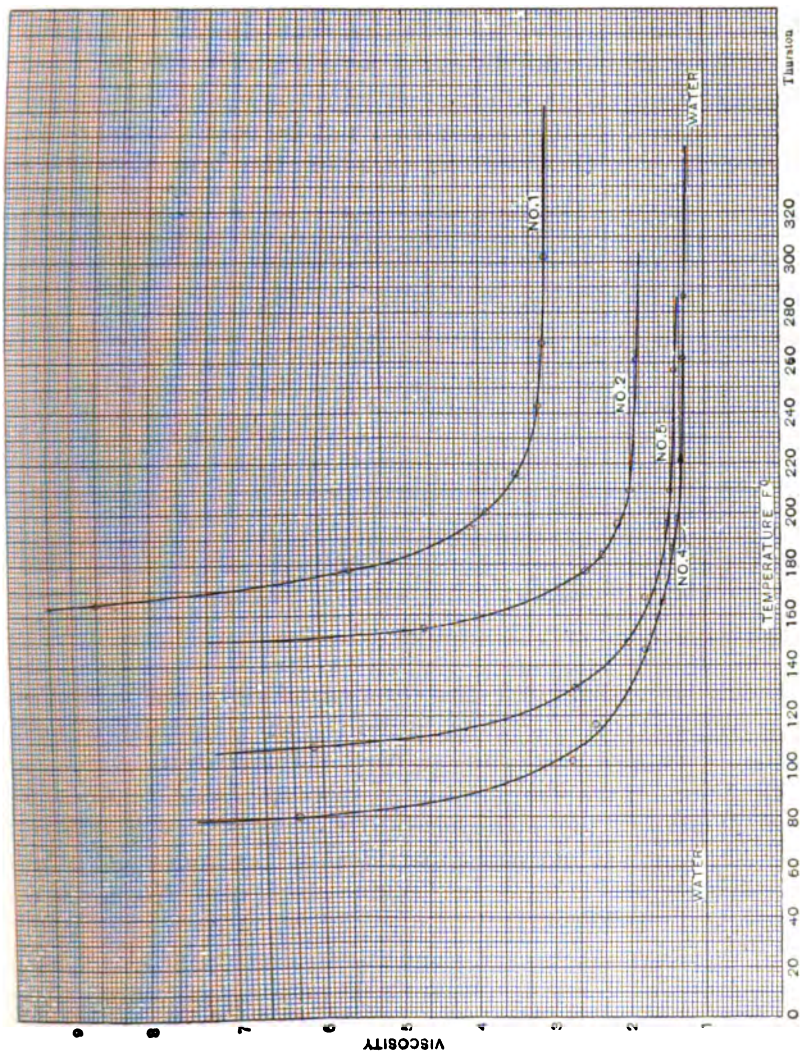

NO.1
NO.2
NO.5
NO.4
WATER
WATER
TEMPERATURE F°
VISCOSITY
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320
1 2 3 4 5 6 7 8 9
Thurston

FIG. 89.

tions for practical purposes, we may compare the diagrams of the paper with those of Figs. 39–41. These are not presented as representing an effort to secure such refinement as would characterize the more deliberate and minutely studied work of research, either in experimentation or deduction, but simply as bringing out the more clearly the difference between ordinary tests and those here discussed, in which every effort is made, and successfully, to insure that the results shall not be complicated by the presence of more than the one variable, the law of which is

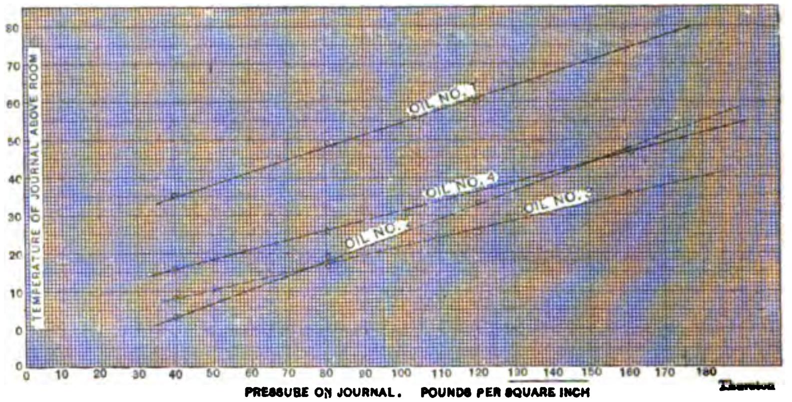


FIG. 40.

sought to be determined. The correspondences are evident on inspection, and it is interesting to see that the commerical work admirably sustains the deductions from the research.

Fig. 39 represents the variation of viscosity with temperature in comparisons of the characteristics of four distinctly different oils: No. 1, an oils old in the market as a "cylinder oil"; No. 2, a "crusher oil"; No. 3, an "engine oil," and No. 4, a moderate-priced "machine oil."

Fig. 40 is a comparison of these oils to ascertain their normal temperatures of steady operation under varying pressures.

Fig. 41 exhibits their relative and absolute friction-reducing values at various pressures.

It is seen that the variation of viscosity, determined in the usual manner, as temperatures change, follow the same general law, and the higher the grade, as rated for the market, the greater the viscosity, *except* that Nos. 3 and 4 are transposed, indicating, possibly, that No. 3 is incorrectly rated and that its

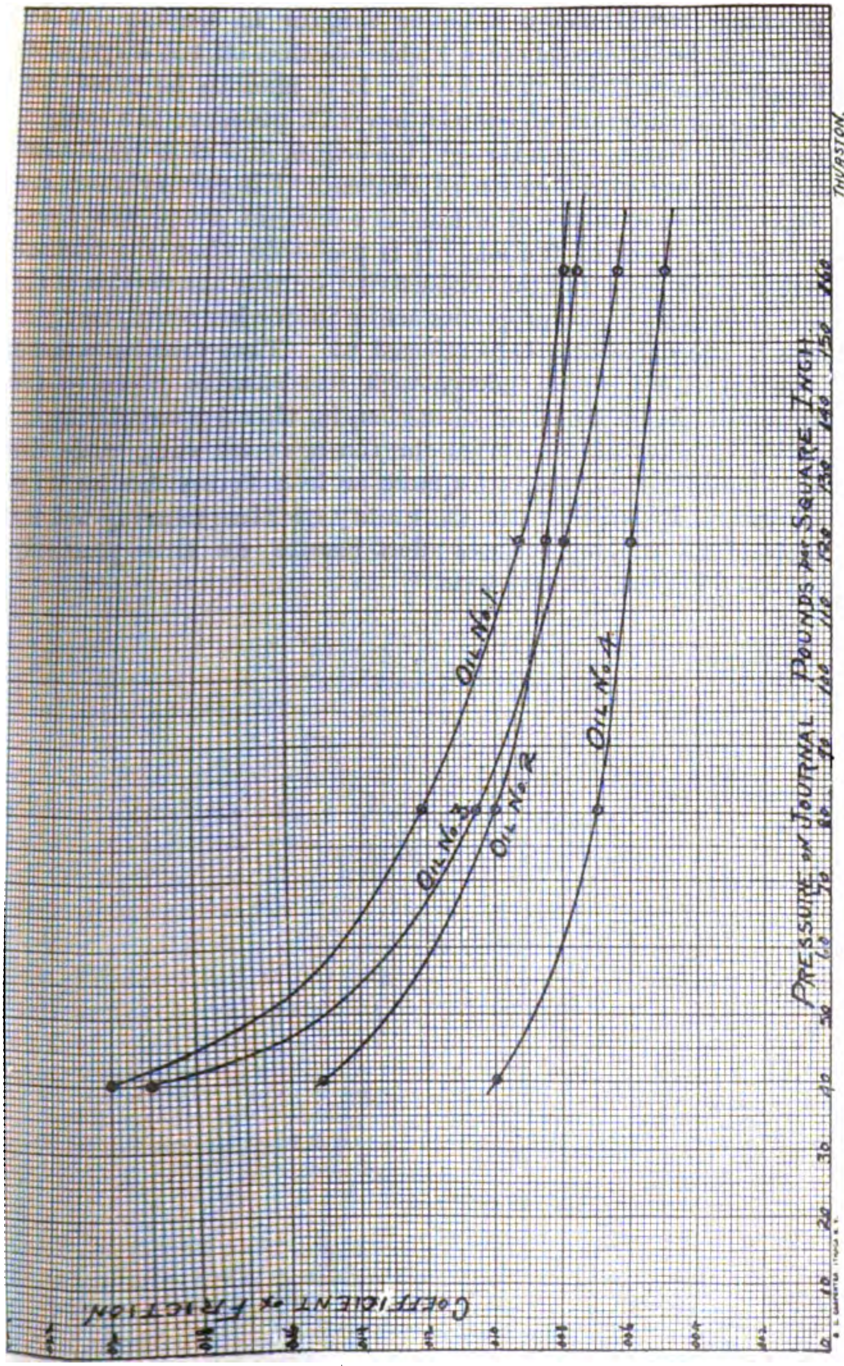

THURSTON.
OIL No. 1
OIL No. 2
OIL No. 3
OIL No. 4
PRESSURE ON JOURNAL POUNDS PER SQUARE INCH
COEFFICIENT OF FRICTION

FIG. 41.

purchaser would secure a better bargain in buying No. 4; although the latter assumes a higher position on the diagram of temperature variation than No. 3. It is also to be noted that the line for variation of temperature with pressure is a straight line which does not pass through the origin, and this would seem to be another corroboration of Professor Kingsbury's remarks regarding the existence of at least two distinct properties, determining the work of friction. It is probable that the friction-reducing property and the conductivity, or the convection of the oil, or both the latter properties acting in conjunction, may give rise to the differences here referred to. The friction-pressure diagram shows correspondence with the results given by the author of the paper under discussion, in the apparently hyperbolic character of the curves for the several oils, while also showing that the curve varies more or less from the line of the equilateral hyperbola when the quality of the bearing and the state of the rubbing surfaces affect results, as they practically always do in the ordinary tests.

No. 960.*

FILING SYSTEM FOR OFFICE USE.†

BY HENRY M. LANE, SCRANTON, PA.
(Member of the Society.)

1. The filing system described in this paper has been the result of a number of experiments, the object to be attained being the preservation of catalogues, clippings, engineering data, photographs, etc., in such a way that they can be used either for general engineering work or in connection with the writing and editing of engineering work. So far as possible, standard devices which can be purchased on the market have been used.

In one of the systems which the writer used for a number of years he had a large collection of letter files upon which various titles were placed and then the material corresponding to the title was placed in the files. This system presented the following difficulties: There was a large amount of dead space, owing to the fact that some of the files were filled up rapidly and others very slowly. Also when the files became full it was necessary to add others having the same title, and these were usually located a considerable distance apart. In this system no card index was used, the titles on the backs of the files being depended upon entirely. In such a system as this, in order to consult the files intelligently it is necessary to have a knowledge of their irregularities, such as duplicate filing cases having the same title located at different points of the system, etc. The system about to be described removes all necessity of burdening the memory with details.

---

* Presented at the New York meeting (December, 1902) of the American Society of Mechanical Engineers, and formingpart of Volume XXIV. of the *Transactions*.

† For further references on this subject, see *Transactions* as follows:

No. 184, vol. vi., p. 863: "Topical Discussions."

No. 539, vol. xiv., p. 780: "A General Engineering Classification and Index." W. L. Chase.

No. 632, vol. xvi., p. 610: "Topical Discussions."

No. 900, vol. xxii., p. 745: "A Method of Filing and Indexing Engineering Literature." G. H. Marr.

No. 946, vol. xxiii., p. 658: "A Technical Index and File." R. H. Soule.

2. When the present system was started all previous arrangements were discarded. As the system now stands it comprises an ordinary Wells Filing Case, as shown at *a*, Fig. 42, and three sectional units, such as are furnished by the Globe-Wernicke Co., two, *e* and *f*, being ordinary letter-box files, and one, *d*, a pigeonhole unit. Under the sectional units there is simply a rough board cupboard, *g*, the use of which will be described later.

FIG. 42.

When a catalogue is received, it is examined, and if it is desired to file it, the various subjects which are to be indexed are underscored. In many cases only the firm name and the principal subject require underscoring, as, for instance, in the diamond-drill catalogue of the American Diamond Drill Co., I underscore the word " American " in the firm name and the word " diamond." After this the catalogue is handed to an assistant, who makes out two cards which go in the card index. One of these is filed under " American " and the other under " diamond." If it were desired to be more explicit the word " drilling " would also be underscored, a third card being headed " Drilling, Diamond " and the card filed in its proper place in the index.

3. The advantage of this system is that if it is desired to replace a catalogue or destroy one at any time it is easy to tell just what cards there are in the card index which refer to the catalogue, and these can be taken out and altered or destroyed as desired. The difficulty with many filing systems is that there is no way of tracing back to the cards from the catalogues, but in this one, before the cards are made out the catalogue is assigned to its proper place in the filing system. No attempt whatever is made to file catalogues by subject, but each one is given two designating numbers or a designating number and a letter, the catalogues being filed according to size. For instance, the catalogue above referred to might be designated as " 326—5," indicating that the catalogue belonged in compartment 326 and that it was the 5th in that compartment; the card referring to this catalogue being marked correspondingly 326—5 in the upper left-hand corner.

4. When looking for information it is only necessary to consult the card index and find what catalogues or other information are required, then to take a scrap of paper and place the proper numbers upon it, and hand it to an assistant, who can obtain the catalogues from the case. In consulting the index it is not necessary to remove the cards from the boxes, consequently there is no danger of misplacing the cards after consulting them. When through with the catalogues they can be returned to their proper place in the files without consulting the card index owing to the fact that the locating numbers have been placed in the upper right-hand corner of the catalogue.

5. Any catalogue which is thick enough to stand in the compartment is filed in this way. Photographs, letters, clippings, or small circulars are filed in the regular filing portfolios shown in the lower portion of the filing case *a*, Fig. 42, and one of which is shown in the supporting rack of the left-hand door of the cabinet at *b*. Attention is called to the two supports which are placed upon the doors of the cabinet, the one at *b* for holding portfolios while examining the material which they contain, and the one at *c* for supporting flat books while being examined. Both of these shelves or supports are arranged so that they drop out of the way when the cabinet is closed. The portfolios each contain twenty-five spaces, which are numbered from 1 to 25, and the consecutive

portfolios are given serial numbers so that anything which is located in one of them can be found by two designating numbers as in the previous case.

6. At first it was quite a problem how to extend this system so as to cover the filing of drawings, blue prints, etc.; but the solution has been found in the pigeon-hole boxes in the Wernicke cases shown at *d*, Fig. 42. Manila-paper folders are made to contain the drawings, the paper being cut as shown in Fig. 43; a tin form of the proper dimensions is laid on as indicated by the dotted lines, after which the three flaps are folded over the tin form and creased down. Each one of the pigeon-hole boxes is given a num-

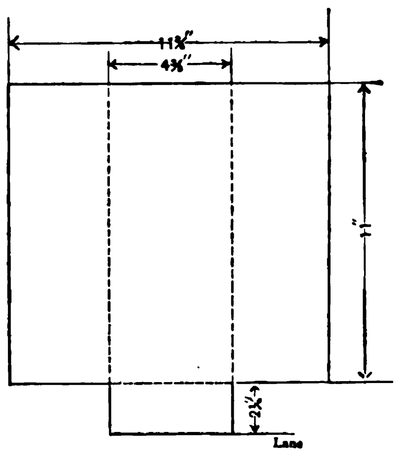


FIG. 43.

ber, and the folders which it contains are numbered consecutively from 1 up, so that everything in one of the pigeon-hole boxes can be found by means of the two reference numbers; a large amount of matter such as specifications, small pamphlets, circulars, small catalogues, folders, etc., being filed in this way in addition to the blue prints and drawings. The title of the material which is filed in each folder is written on the back of the folder with words underscored corresponding to the words on the index cards. The regular letter-file units are used for photographs and similar material, though it would be possible to get along without them by having more of the portfolios as shown in the lower portion of the Wells cabinet, Fig. 42.

7. This system works admirably for uniform-sized catalogues, but odd sizes give more or less trouble. Large thin catalogues

have been folded up and filed in the pigeon-hole boxes or in the letter files, but large catalogues of irregular size with stiff binding have proved a source of considerable annoyance, and in some cases have been ruthlessly destroyed on account of the fact that it was impossible to file them advantageously. Large bound catalogues are given serial numbers as in the ordinary library index and are kept on top of the Wells cabinet and on suitable shelves, which are not shown in the illustration.

8. A few words concerning the card index which accompanies this may be of interest. The first idea was to have the card index placed in one of the units of the Wernicke sectional files, but in order to protect the index from fire losses a set of ordinary drawer files was finally adopted. At present the writer has six of these files in use. The cards are 2 by 5 inches. In the upper left-hand corner are entered the two figures, or figure and letter, corresponding to the place in which the catalogue or other material is filed. The upper line of the card contains the title corresponding to the underscore in the catalogue for which the card was made out. Frequently some additional information concerning the catalogue is entered on the card, and in many cases where it is desired to file some small bit of information, such as a formula, the information is all entered upon the card, at times the back as well as the front being utilized for this purpose. In such a case as this no reference letters of course are necessary, as the card itself contains all the information.

9. As the system grew it became quite a task to look through the large accumulation of cards to find any given subjects, hence the use of auxiliary guide cards was adopted. For instance, under the letter M the ordinary subjects were filed in consecutive order, Ma, Me, etc., but it was found that there were many cards headed "Machinery," "Milling Machinery," etc., so that the idea of separating these and placing them at the back of the M file, just forward of the N's, giving each a separate guide card, occurred to the writer. For instance, the M series in the index at present is arranged as follows: The miscellaneous M's occupy about one hundred and twenty-five cards; back of this there is an auxiliary guide card headed "Machinery," under which there are about seventy-five cards; next a card headed "Milling Machinery," with about fifty cards; then one headed "Mining Books," with about twenty-five cards; one headed "Mining Laws," with about twenty-five cards; one headed "Mining Matters, Miscellaneous," with about

sixty cards; one headed "Mining Machinery," with about forty cards; one headed "Mining Schools," with about thirty cards. These auxiliary cards reduce the number it is necessary to look over to find any ordinary subject, and they facilitate the location of any matter relating to the special subjects covered by the guide cards most often consulted, as a man would naturally divide his work according to his wants, and the cards for the specialties which he needed would accumulate more rapidly than others.

10. Another advantage of having the card index in these drawer files is that, in case the regular system should be destroyed by fire, a clerk or stenographer could replace a great deal of the matter by simply writing for the necessary catalogues and information and arranging them in new filing cases; it is probable that at least 60 per cent. of the matter in the writer's files could be replaced in this way.

11. A feature of this filing system is the rough set of shelves shown at *g*, Fig. 42, on which are arranged a series of envelopes containing pamphlet copies of the papers read before the American Society of Mechanical Engineers and the American Institute of Mining Engineers. In many cases both the preliminary and revised papers are kept, being simply placed in envelopes and arranged according to meetings. Any one of these can be found very quickly, the regular index and bound volumes being used to locate the original paper and find out at what meeting it was read, after which, by a reference to the envelopes, the pamphlet paper can be located.

DISCUSSION.

Mr. Geo. L. Fowler.—I find, on looking over this system, that it is practically identically the same thing which I am using in my own office, of which I spoke in connection with Mr. Soule's paper at the May meeting in Boston. I have five card catalogues which are separate and distinct. One is the card catalogue of trade catalogues, which I underscore more fully than Mr. Lane, in that I underscore every individual item that any manufacturer will make; so that in case I am looking up to get the prices for any one item I can simply say, What have we got here on mandrils, lathes or anything, and I immediately have all of the catalogues available. In addition to that I have a card catalogue of all outside blue prints or drawings which have come to the office in any way, and which have been kept and filed.

These are numbered and filed with the titles placed upon the card catalogue. Of course their numbering is without any reference to subject matter whatever, and the same thing holds true of clippings and references to articles in magazines and books in my library. That enables me to see what there is available on any one particular subject. Then, in addition to that, I have a card catalogue of all of the drawings which belong to the office itself—that is, drawings which have originated in my own office. These are kept filed, and get consecutive numbers. Drawings which have been made for outside parties and which have been delivered to them, I simply keep blue prints of for my own reference, and those are filed by themselves. Then finally I have a card catalogue of my library which is arranged in exactly the same way as any card catalogue is arranged for an ordinary library. That makes five complete catalogues; everything separate and distinct by itself, and of course everything available; but so far as the method of handling the work is concerned, it is done practically identically the same way which Mr. Lane has outlined in his paper.

Prof. Wm. W. Crosby.—In the ordinary business of an office there are many cases where correspondence is received, which, unanswered at the time, requires no further thought. Very often the names signed to the letters are not brought to one's attention again, but in the course of some months the subject matter of the letter is recalled, while the name of the writer cannot be remembered. A card catalogue provided with cross index is most valuable in such a case. Offices which have had no use for card catalogues in other ways, have found that in this particular case the indexing was most valuable.

Mr. W. E. Partridge.—There are two points in establishing and carrying out card-catalogue systems worth attention which have not been mentioned. The first is, in each division arrange your materials so that when you have found a place in the index the thing sought is before you. If borne in mind, this may easily be effected. The second one is, in a large establishment, allow any one access to your index and files, but allow only one person to put anything back after it has been removed from its place.

Mr. L. R. Pomeroy.—There is one item connected with this subject which has not been touched upon, which seems to me worthy of interest, and that is the method of filing; namely, the so-called vertical-filing system. These files can be used in connection with card indexes with a practical and satisfactory result. By a subject-designation of the compartments in the vertical file, indicated by numbers, all letters or correspondence or data with reference to this particular subject, although originating in many different places, carry the same number, and naturally gravitate to the same compartment.

We find this an excellent method. I use it myself with the Dewey system of classification and numbering.

The Dewey system of classification is comprehensive and complete, and lends itself readily to use in connection with an ordinary filing clerk, for the reason that it is not necessary for the clerk to know anything concerning the subject classification you have in mind, but to file the article by the number which you have placed against the subject in question at the time you came across the item in the general course of reading.

Mr. H. H. Suplee.—There is one other point, I may state, in regard to having things put back in their proper places. In our experience with the *Engineering Magazine* index, we have to prepare an index each month of six or eight hundred cards, and let it go out of our hands for several days to the printer. If a box should be dropped or the cards mixed, everything would go wrong. So the rule is that before the index is sent to the printer's the cards are numbered on the backs from one up, so that if a box should be "pied" any one in the printing office could sort them out. When the copy for Vol. III. of the *Engineering Index*, containing forty to fifty thousand cards, was sent to the printer's, it was all numbered from beginning to end. Of course, in a private establishment where cards are put in and taken out, there would have to be sub-numbering where other cards are put in. At the same time it might save some trouble to have the serial order of the cards in some way indicated on them in case of accident.

Prof. H. W. Spangler.—I think one of the serious questions in the use of card systems is the determination of the subject under which you are going to place these things. It is curious how a man's mind changes from one week to the next. One week he decides to put a thing under "Milling machines," and the next week under "Machines, milling." Very often you think a reference is under a certain heading; you look for it and fail to find it, but the next week you find it under some other head. Of course engineering matters change, and a thing that five years ago you would have indexed under "Horseless vehicles" or "Vehicles, horseless," to-day you will put under "Automobiles" or "Electric automobiles" or dear knows what. So one will find, if not very careful in selecting subjects under which filing is done, he might as well throw them in the waste basket at the beginning. I know it is the case that there are dozens of combinations of words which at one time or the other are rational for any particular thing. And your clerk or somebody had better go over that list of a dozen things, if you want to find any particular article which you may want, or the particular catalogue you are looking for. So, for my own purposes, I have a typewritten list on my desk, and the thing must go under a word in that list. If the advance in engineering is such that a new word has to go in, then I agree that everything on that subject up to date is lost. I have not got time enough to go through this card catalogue and pick out all the things that might go under this new word.

Mr. Suplee.—That very subject came up to us in making the *Engineering Index*, particularly in the last volume, and the only remedy we could find was to have plenty of cross cards. Each subject was indexed under the most satisfactory title we could find, and then cross cards indicating that word were put in for every imaginable word that we could think of, under which anybody would be likely to look for that article. If that is done carefully, I think it will get rid of the trouble. You must be generous with your cross cards.

Mr. Spangler.—I think the last volume of the *Engineering Index* carries that out. I have hunted under a dozen different subjects before I found a reference to the particular thing I was after, but that is better than not finding it at all.

Mr. Suplee.—Of course we do not make that index for our own particular use. We were making that book for every one to use, and, of course, we had to put in the words that any man might happen to think of.

*Mr. H. M. Lane.**—I will say one thing: I found the last volume of the *Engineering Index* the best index I have had to deal with. Those cross cards have helped me a great deal. I have had to make the indexes for several books. The publications in my department are all indexed by me personally, as a

* Author's closure, under the Rules.

rule, and the cross index is the only way to locate a great many things. Sometimes a given subject must be indexed four or five times under different words so as to be sure that every one can find it. The trouble is that our engineering books are not cross-indexed enough. There are one or two pocket books in the market which have made me extremely mad because I could not find what I wanted in them. In regard to other filing systems, some remarks have been made here about having special card systems. I have five card systems in my office, but I have only described one here. This one is for my general catalogue filing, and so on. The others are for special purposes, to keep track of different things in the office—names of men who are available along certain lines of work, or names of our students who are carrying on certain lines of work, and various things of that kind. I have five separate systems. That idea of letting any one at your files and only one person to return things to them I had to come to about a year ago on one file, and I finally came to it on all of them. The orders are now that no file-card box shall go outside of a limited space near the safe in my private office. There is a table there, and under no circumstances is anybody to take a box away from that space. They can come there and consult them, they can take the catalogues, etc., anywhere they please, but when they are through they bring them back and lay them on that table, and one person files them again. It is the only way, I think, you will ever be able to locate things. At one time I allowed some of our text-book writers free access to my files, including the returning of matter, and it cost me a good many dollars last summer to have the whole file system gone through from beginning to end, to check all numbers and see that everything was in its proper place, and the cards gone through to see that they were all correct. But it is straight now, and I hope I can keep it straight.

In regard to the Dewey system and similar systems, I had some experience with them, and our trouble has been that I could not keep the material in as small a space as I could with this system. With this system you do not need to have any more filing space than just a little beyond where you are filing. Another objection I have found to these systems is that when new subdivisions are made, much of the old matter must be re-indexed.

No. 961.*

ENTROPY ANALYSIS OF THE OTTO CYCLE.†

BY SIDNEY A. REEVE, WORCESTER, MASS.
(Member of the Society.)

1. THE object of the following note is to call attention anew to the advantages of submitting all heat-engine records to the entropy analysis, and to the ease with which this may be done in the case of tests of gas engines of the Otto type.

The note is based upon the tests submitted to the Society at its meeting of December, 1900, by Prof. C. V. Kerr. This particular test is chosen not because of anything peculiar to the test itself, but only because it is representative of first-class work on a standard engine, all the particulars of which are already before the members of the Society. The writer has translated the sample indicator-cards published in vol. xxii. of the *Transactions*, pp. 157-162, into entropy-temperature diagrams, some of which are reproduced herewith. Before proceeding to discuss the showing they make, some reference is necessary to the manner of their production and to their reliability.

2. It has frequently been urged that such diagrams are worthless, because no knowledge is to be had as to the temperature of the working fluid at the inception of the cycle. This objection seems to me to be irrelevant, because almost the full value of the analysis lies in the revelations as to *comparative*, not *absolute*, changes of temperature and entropy. Moreover, much light is thrown upon this basic unknown quantity, the initial temperature, by the very analysis which depends upon it. A single degree of difference in temperature at the beginning of the cycle results

* Presented at the New York meeting (December, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

† For further discussion on the same topic consult *Transactions* as follows:

No. 514, vol. xiv., p. 214: "Notes on the Refrigeration Process and its Proper Place in Thermodynamics." Geo. H. Richmond.

No. 771, vol. xix., p. 477: "Thermodynamics Without the Calculus." Geo. H. Richmond.

in a difference of 5 degrees at the calculated upper limits. Considerable accurate information is already at hand concerning these upper limits under varying conditions of operation. Therefore the assumptions made in regard to initial conditions can be checked away from egregious error by the results which they incur. In all of the present work the initial temperature was assumed to be 600 degrees absolute, or 139 degrees Fahr. The figure was chosen largely as a convenient round number; but it is evident from the results that it cannot be far out of the way.

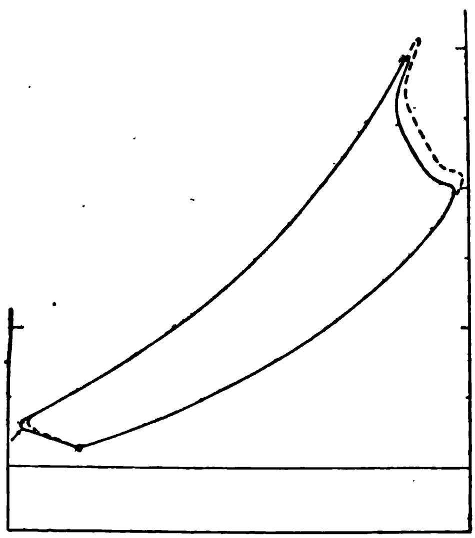


FIG. 44.

It is at any rate not too high, for the final temperatures calculated from it all fall below frequently recorded maxima.

The initial pressure is also open to conjecture; but its effect upon the results is much less marked. Fig. 44 shows the effect upon the analysis of an error of 0.5 pounds per square inch in the determination of the initial pressure, an error greater than could possibly be excusable in such a determination. The full-line diagram assumed an initial pressure of 14.6 pounds, the dotted line 14.1 pounds. The diagram is shifted upward and to the right; the heat apparently abstracted by the cylinder walls during compression is considerably affected. But the form of the expansion line, which is the main consideration, is practically unaltered.

There is, of course, considerable error due to inaccurate reproduction of the indicator diagrams in print. That is discounted by the number of diagrams analyzed and by their unanimity on certain points.

3. The one open question of the Otto cycle in regard to which these diagrams speak in no uncertain tone is that of the so-called "after burning." Since the gas engine's first appearance it has been noticed that the expansion curve of the indicator diagram usually shows pressures rising above the true adiabatic. The explanations offered have precipitated all the discussion as to "stratification," dissociation, and delayed combustion. If the

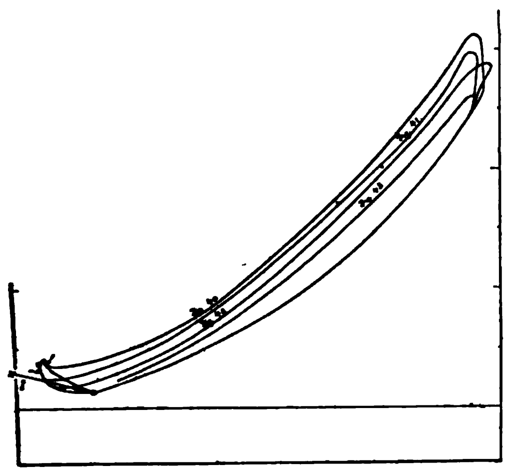


FIG. 45.

expansion line of almost any entropy diagram from such an engine be examined, it will be seen at a glance that, as is true of all those presented except Fig. 45, which represent abnormally late ignition, (1) they are all concave toward the right, and (2) the concavity is produced by an initial departure toward the left, followed by a portion practically vertical and finally by a departure toward the right. While the form of the expansion part varies considerably in detail among the several diagrams, these generalities hold true of all of them.

The great isomorphic curve sweeping upwards and to the right represents, of course, the rise in temperature due to the development of heat by internal combustion. Were this process not modified by environment it would carry the diagram to about *A*, in Fig. 46, and to some similar elevation in the others. It is prevented from doing so by the simultaneous abstraction of heat by the cylinder walls, cooled by the water jacket. This process of abstraction is the exact opposite, in its effects and in its graphi-

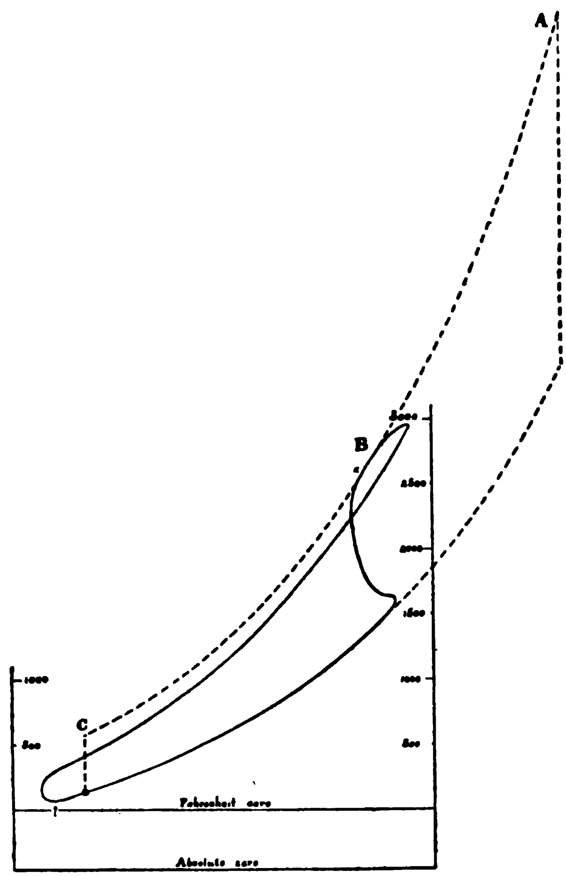


FIG. 46.

cal representation, to the supply of heat by combustion; it therefore does not tend to divert the cycle from the isomorphic path *C B A*, but merely to bring it back from *A* to *B*.

4. At the x-mark, which denotes the inner dead centre, the theoretic normal path of the cycle changes from the northeasterly one of the isomorphic to the due south of the straight, vertical

adiabatic. If now the supply of heat were to continue after the piston has started on its stroke, the diagram must show departure to the right from this adiabatic, or into a path lying somewhere between due south and east, or between south and northeasterly in any event. But in no case does it do this. The next portion of the diagram bears in every case to the west of south. This shows an abstraction of heat from the working fluid, not an addition, during the first portion of the expansion after maximum temperature has been attained.

5. Whether the time of maximum temperature coincides with dead centre or not depends upon the time of ignition. If that occur at or very shortly before dead centre, all or a large portion of the combustion must take place after the expansion stroke has been entered upon. But even then, unless ignition be so long delayed that the gases have not possibly time to fairly burn before exhaust occurs, there is a perfectly definite limit to the period of combustion. The maximum temperature is attained by a close approximation to the constant-volume process and almost synchronously with attainment of maximum pressure. After this point is reached there is no further development of heat. The entropy shows no further increase as expansion begins and the temperature falls.

6. The only premises upon which is tenable the supposition that there is further development of heat would be, that while such development of heat from combustion might still continue, it would be at a lessened rate, such that the absorption of heat by the walls overbalanced it and made the net result a loss of heat. But as actual expansion progresses, as revealed by the entropy diagram, its southwesterly end slowly and continuously alters itself, first, into a southerly direction, and finally into a southeasterly one. To explain this on the basis of a balance between a remnant of tardy combustion and chilling walls, it must be accepted that the balance, which at B showed a sharp reversal from positive to negative, later experiences a slow reconversion in favor of combustion. Either the rate of heat supply from delayed combustion must be on the increase, or the rate of abstraction must be on the decrease. The first supposition is quite untenable, on general considerations. If reliance be placed on the second (which is an altogether probable fact) for explanation of the revealed process, it is necessary to assume that the delayed combustion is prolonged quite until the expan-

sion stroke is complete, even in those cases, such as Figs. 46–50, in which ignition occurs long before the stroke begins, and in which the bulk of available heat is already developed at dead centre.

7. To the above argument it may be added (in order to anticipate the objection) that, so far as the diagram gives evidence, it is still mathematically possible that a minor development of heat may continue after maximum temperature has been attained; but the probabilities are quite the opposite. Such a fact would necessitate a double reversal of the balance between gain

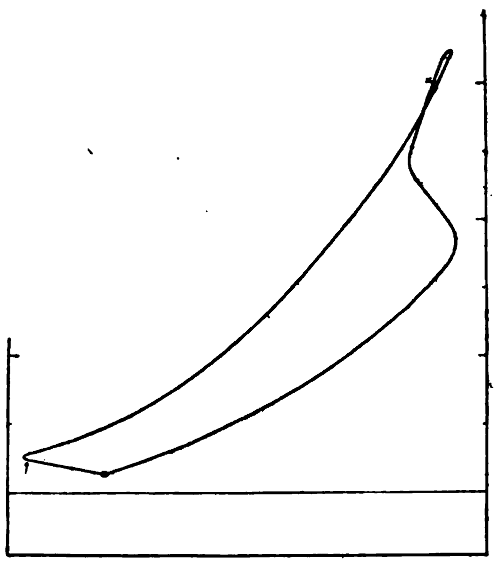


FIG. 47.

and loss of heat, and such arbitrary double reversals do not coincide with the general laws of equilibrium.

8. Finally, it is to be pointed out that the general form of this entropy-diagram expansion-curve from the Otto gas engine is identical with that normally produced by the non-jacketed steam engine, where there is no possible source of supply of heat to the steam, except from heat already stored in the walls by the working-fluid at the beginning of its cycle. The supposition of a similar process in the gas engine to that of condensation and re-evaporation in the steam engine offers full and simple explanation of the stated problem. At the point of maximum temperature the walls have already received some 30 to 50 per cent. of the

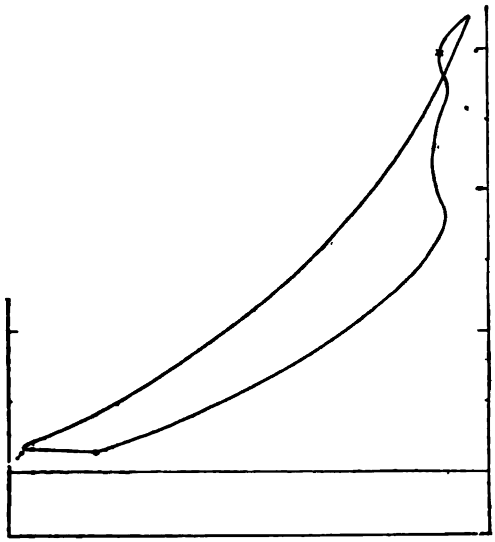


FIG. 48.

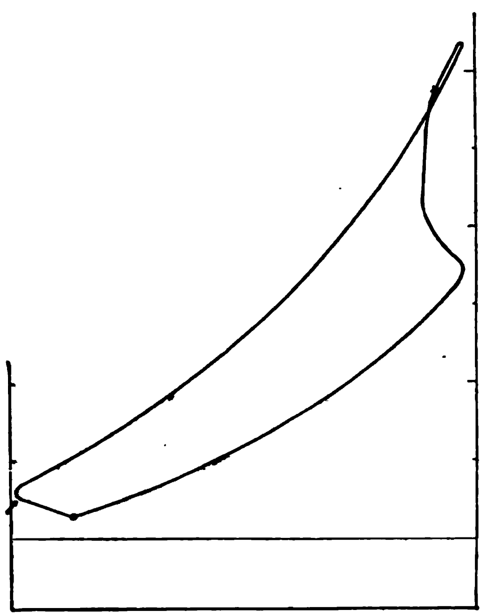


FIG. 49.

total available heat in a very small fraction of a second. There has been no time for the distribution of this heat throughout the iron. The inner skin must be very hot. In another very small fraction of a second the temperature of the gases has been much reduced by expansion. It is quite natural that a small portion of this heat in the walls (the diagrams show it to be about 6 per cent. of the total supply; see item *a*) should return to the gases, instead of continuing through the metal to the water jacket.

9. At the end of the expansion process most of the diagrams show a little "toe-out," which is worthy of remark. Such sharp changes of curvature, when occurring earlier in the stroke, particularly near the maximum-pressure point, are easily explained as due to indicator waves, or, in the present case, to error in re-

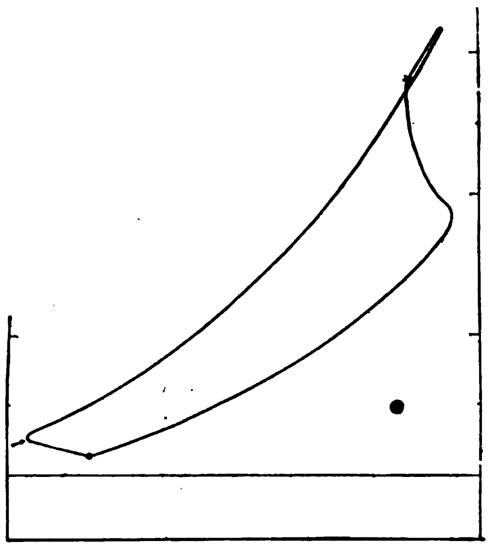


FIG. 50.

production. But at this portion of the diagram neither indicator inertia nor indicator friction will explain the waver from the vertical, and the toe occurs too persistently in the same portion of most of the diagrams to be attributed to graphic error. If it is to be explained by return of heat from the walls to the gases, such return must be very active. In some cases the expansion here becomes almost isothermal. There is no greater difficulty in understanding how the walls maintain approximately isothermal expansion at this portion of the cycle, however, than how they maintain compression so nearly isothermal at the beginning of the cycle. Certain it is, at any rate, that practically all of the many gas engine indicator cards which I have analyzed show this right-handed concavity of the expansion line, and many of them show the toe-out at the foot of it. The only case in which development of heat was observable after maximum temperature was attained was that of a 100-horse-power Crossley engine driven by very thin Dowson gas.

10. As to the compression process, every card hitherto analyzed shows abstraction of heat by the walls during compression. At the same time, the diagrams here submitted corroborate, by their general temperature range, the evidence offered elsewhere that the initial temperature of the charge at the beginning of compression is substantially higher than when entering the cylinder. How is it that the walls which certainly abstract heat during compression imparted it during the previous suction? I do not pretend to answer. Possibly the admission valves, etc., are hotter than the cylinder walls. Possibly the apparent problem is much exaggerated over the real, as it would be by error in assuming or observing the initial pressure as greater than it actually is.

The last diagram presented, Fig. 51, is from Professor Robertson's test of the 125-horse-power engine. Although the conditions of operation are totally different from those in Professor Kerr's case, the similarity of result, when compared with the normal ones of Professor Kerr's set, is most marked. The engine is large; the walls are less active; little cooling after maximum temperature is visible. But there is no after-burning; the heat imparted to the gases late in the expansion stroke is separated from the period of combustion by a distinct period of adiabasis; the isothermal toe at the foot of the expansion line is present as usual.

11. In view of the above, I respectfully submit that no observer of a gas-engine test, any more than of a steam-engine test, has done his proper duty by his task until he has submitted his results to the entropy analysis. No other person than he, with his intimate knowledge of all conditions, can possibly do it so accurately or intelligently. Since it is my observation that the task is often avoided for fear of its burden or its mystery, I append hereto a facsimile of the work involved in deriving the diagrams here submitted. It is assumed that the investigator is provided with an indicator card, on which are laid off the axes of absolute zero of pressure and volume, the latter being, of course, the clearance line; with a slide rule (or preferably two of them), and with a table of logarithms. For the last either Naperian or com-

mon logarithms will do; four-place logarithms are sufficiently accurate, and a table which covers not more than a single pair of pages for all numbers will greatly enhance convenience of work. The indicator diagram is assumed to be marked with any desired number of designated points.

12. The work proceeds according to the following argument:

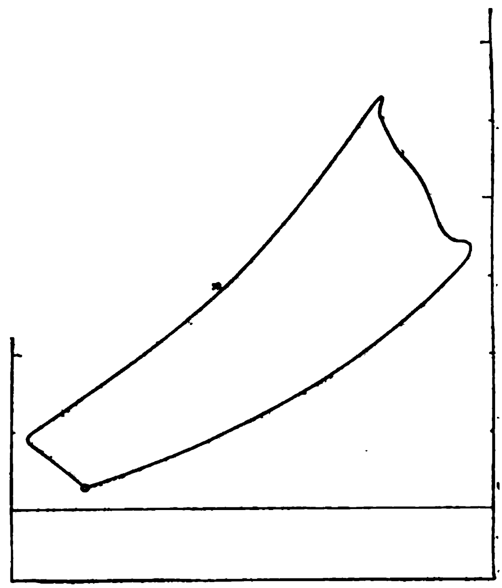


FIG. 51.

From any given zero-point the entropy and temperature for any other point may be expressed by the following equations:

$$(a) \qquad \frac{PV}{T} = \frac{P_0 V_0}{T_0}; \text{ therefore } \frac{T}{T_0} = \frac{P}{P_0} \div \frac{V_0}{V},$$

and

$$\log \frac{T}{T_0} = \log \frac{P}{P_0} - \log \frac{V_0}{V}.$$

(b) $N - N_0 = s \log \frac{T}{T_0}$, in which N signifies entropy and s the specific heat involved.

13. Any point on the indicator card can be reached from the origin of the cycle (at the beginning of the compression stroke) by traversing, first, the horizontal atmospheric line until directly

beneath the desired point, and then the ordinate rising vertically to the point. The first path represents, thermodynamically, cooling under constant pressure, the range of temperature being given by the ratio $\frac{V}{V_0}$; the second represents heating under constant volume, the temperature range being given by the ratio $\frac{P}{P_0}$. In the first case the specific heat involved is 1.408 * times that in the second. Therefore,

I. With the slide rule set to the initial absolute pressure take each point on the card in turn, divide the pressure at that point by the initial pressure, and note the logarithm of the result.

II. With the slide rule set to the total length of the indicator card (including clearance) divide it by the total volume at each point of the card in turn.

III. Add to the second $\frac{408}{1000}$ of itself by slide rule or by arithmetic.*

IV. The difference found by subtracting III. from I. is the *entropy* of the desired point.

V. The difference found by subtracting II. from I. is the logarithm of the temperature ratio; this logarithm should be set down at one side.

VI. With the slide rule set to the initial absolute temperature, enter the table of logarithms with V., and multiply its number by the initial temperature; the result is the *absolute temperature* of the desired point.

Thus: (Let $T_0 = 600°$ F.)

I. $\log \frac{P}{P_0} = 1.0792.$	IV. Entropy $= 0.4075.$
II. $\log \frac{V_0}{V} = 0.4771.$	V. $\log \frac{T}{T_0} = 0.6021.$
$\frac{4}{10}$ of ditto $= 0.1908.$	VI. T absolute $= 2400.$
III. $\frac{8}{1000}$ of ditto $= \frac{0.0038}{0.6717}.$	T Fahrenheit $= \frac{460}{1940}.$

In this way some twenty points, or sufficient for an entire analysis, can be calculated and plotted inside of an hour.

* Lummer E. Pringsheim, in an investigation the report of which had not reached the author at the time this paper was written, gives the value 1.4025 as more accurate than this. 1.404 would be more convenient to use and is probably sufficiently accurate for all engineering purposes.

DISCUSSION.

Mr. H. H. Suplee.—I would like to ask Professor Reeve a single question. This paper, of course, refers to engines operating on the Otto cycle. The termination of the upper line of explosion in these is definite and determined, I believe. How would that be in the case of internal-combustion engines operating by combustion rather than by explosion—engines of the Diesel type, for instance, in which the fuel charge is varied and burns continuously until cut off. Is the same also true of them, or is it true only of explosion engines?

Professor Reeve.—It holds true of one or two cards of the Diesel engine which I have analyzed, but I have not had enough experience with the Diesel type to speak broadly and definitely.

Mr. Suplee.—I understand that in the Diesel motor the amount of fuel introduced is not constant, but varies. The oil is injected continuously until it is cut off by the action of the governor, while in the gas engine a definite charge is drawn in and exploded each time, so that the law may not be alike for both.

Professor Reeve.—The same argument would follow nevertheless. The frequent bending over of the isomorphic curve of combustion in the Otto engine is due to the motion of the piston before combustion is complete, so that the more the piston moves during combustion the more the line is bent over. But the point of the argument is that when the combustion is complete there is a sharp end to it. Although the piston continues its motion with smooth acceleration and the pressure-volume curve shows no abrupt change, the entropy-temperature curve reveals graphically, by its sharp reversal, the basic change in the thermal processes at the instant when combustion is complete. It is apropos to the Diesel as well as to the Otto.

(Added after adjournment.)* In a discussion of the applicability of the entropy analysis to the Diesel cycle before this Society (Vol. XXI., p. 285), it was urged that the presence of the air-pump, injecting fuel and compressed air into the cylinder during combustion, vitiated the conclusions to be drawn. It is of interest to point out in this connection, that thermo-dynamic processes do not recognize questions of locality. The compression of air by the air-pump is just as much a part of the thermo-

* Author's closure, under the Rules.

dynamic cycle as is the compression in the main cylinder. In regard to the added working substance involved in the entrance of the oil, I would say, for the analysis of either Diesel or Otto oil-engine cycles, that the results of this addition, as I have calculated them, have so uniformly adhered to an increase of specific volume during combustion by 2 per cent., that I now take no more cognizance of the oil than to make this standard allowance. Moreover, any error in this assumption, which applies only to the line of combustion, could have no effect upon the main point at issue—viz., the form of the expansion-line and its similarity in internal-combustion engines to its standard form in steam engines.

No. 962.*

A RATIONAL SOLUTION OF THE PROBLEM OF WEIGHTS AND MEASURES.†

BY SIDNEY A. REEVE, WORCESTER, MASS.
(Member of the Society.)

1. The question of what system of weights and measures most fully meets the demands of the technical world has recently received renewed discussion. The source of this fresh impetus has lain in the projection of a national law, the adoption of which would render the universal use of the metric system compulsory. It is not the object of this paper to undertake discussion of the merits of this bill; it is to present briefly some of the advantages to be gained from advance in another direction. This alternate line of progress has already been ably advocated, at one time or another, in a general way; but the concrete programme for procedure which is herein presented has never yet been suggested, so far as the writer is aware.

2. As a preliminary step some of the fundamental attributes of the metric and the English systems will be outlined as the writer sees them. In doing this no attempt will be made to conceal the firm opinion that the metric system is not naturally and inherently adapted to industrial needs, and that to commit ourselves finally to its universal, compulsory adoption would be a mistake of immeasurable magnitude. But the writer also disclaims any belief that the metric system has been proven by experience incapable of adoption in engineering and industrial works. Locally and occasionally it has been so adopted. There has been no resultant catastrophe. There has not always been even resultant

---

* Presented at the New York meeting (December, 1902) of the American Society of Mechanical Engineers; and forming part of Volume XXIV. of the *Transactions*.

† For further discussion on this topic consult *Transactions* as follows:
No. 4, vol. i., p. 29: "The Metric System." Coleman Sellers.
No. 721, vol. xviii., p. 492: "The Metric System Versus the Duodecimal System." George W. Colles.
No. 923, vol. xxiii., p. 291: "The Linvolpon System." F. F. Nickel.

rejection. But it is broadly and plainly true that the resultant gains have not been sufficient to spread appreciably the field of experiment with the metric system—not even so rapidly as industrial effort has extended. For thirty-six years the use of the metric system has been open to all who cared to try it. In all these years the proportion of those who did to the whole number who might has not perceptibly increased.

3. The reasons for both the continued advocacy and the continued rejection of the metric system are plain. They are parallel and quite compatible.

(*a*) The metric system is attractive because its measures are arranged on the same system as our numerical notation.

(*b*) The metric system is cumbrous because it is decimal in its arrangement.

4. To state that the advantages of the metric system lie in the fact that its arrangement is decimal is erroneous and deceptive. Had our numerical system been based upon the octonal or the duodecimal plan, the scientific originators of the metric system would have adopted just as promptly and have urged just as vehemently a system of weights and measures also based upon the octonal or duodecimal plan. If that had been done the then system would have every advantage now offered by the metric. In addition it would have many more.

5. To support this last statement properly would be to duplicate much which has already been written, more ably than could be reproduced here, and which is accessible to every reader of these lines. In particular, in vol. xlix. of the *Popular Science Monthly*, will be found a full and cogent statement by Mr. Herbert Spencer of the reasons why the metric system has not found wide adoption. In the same volume is a counter-defence by one of the ablest of the advocates of the metric system, Dr. T. C. Mendenhall. No engineer may presume to a worthy opinion upon the weights-and measures question without acquaintance with these writings.*

6. To summarize very briefly, Mr. Spencer's position is :

(1) That the natural evolution of systems of measures by popular adoption or rejection, or by the survival of the fittest, has ever been away from decimal divisions and toward the repeated division of a unit by twos and by threes.

---

* It is assumed that all readers of this paper are already acquainted with the earlier discussions of the metric system before this Society, to which no concrete reference is made.

(2) That this tendency has been only very slightly affected by the parallel presence of decimal systems of division, even when made compulsory by law.

7. Thus, in this country a decimal division of currency has been compulsory by law for over a century, and is backed by all the inconveniences involved in the departure of money-division from the standard system of notation, which is decimal. Yet the division of the standard unit, the dollar, by other factors than those of ten and its powers, by factors of two, three, four, six, eight, twelve, and sixteen, is practically universal. Of the three decimal divisions of the dollar; the dime, the cent, and the mill, the first and the last are unheard of as units of price in ordinary retail business; the other, the cent, is almost as apt to be split by a vulgar fraction as it is to be used in its integral purity. Of all our coins the favorites are the "half" and the "quarter." The dime is used much more to make change for the quarter, because five nickels are too cumbrous, than it is as one-tenth of a dollar. We could not get along without the half-dime, or "nickel." The cent is scarcely ever used to make change for a dime. In short, decimal subdivisions are much too far apart.

Even in the choice of rates of interest, where the burden of calculation is a maximum in proportion to the coin actually handled, there is little disposition to retain the decimal system. Fractional portions of units per cent. are not often stated as tenths, but more commonly as halves or quarters or eighths.

This is the final, present result of a century's experiment with a decimal system supported by legally compulsory adoption. In other countries and in other lines of measure than the monetary the experience is parallel. In short, all the advantages of having a system of measures upon the same basis as the system of notation are not sufficient to countervail the disadvantages of conducting the day's work upon any other basis than division by twos and threes.

8. Even in scientific work the same trouble is found. So long as instruments, scales, etc., are divided on the decimal system it is of course easiest to read them so. But when that artificial constraint is exceeded the natural basis for either estimating or assigning divisions is by twos or by threes. Every student has to be arbitrarily taught to estimate to tenths, and even then the result is inaccurate. Every intelligent young observer, on the other hand, naturally estimates well to halves, thirds, and quarters.

In my own work, although I carefully instruct at the start against using numerical statements to a greater degree of accuracy than is naturally possible, yet I sanction and believe in observations made and stated in estimated divisions such as 0.25, 0.33, etc. For the observer to estimate to tenths is difficult and inaccurate; to attempt to estimate to hundredths is absurd. Yet I more highly esteem the accuracy of such estimated divisions as those above stated than I do stated estimates of 0.2, 0.3, 0.4, etc.

9. It is only because scientific work involves so large a proportion of computation to a given amount of mensuration that the metric system is popular among scientists. For pure mensuration nothing will ever be able to compete successfully with the two-foot rule, with "two pints make one quart, four quarts make one gallon," with "twelve units make one dozen, twelve dozens make one gross," etc.*

10. But even for computative, scientific purposes a duodecimal system of both measures and numbers is infinitely to be preferred to a decimal system of both measures and numbers. The reasons are these:

(I) For *Mensuration* the advantages are as just stated.

(II) For *Computation* : (*a*) The mental burden involved in carrying in the head a duodecimal multiplication table, and in performing with it the simplest arithmetical processes, is much less than with the decimal system. One has only to faithfully try this experiment to be convinced.

(*b*) The degree of accuracy of a given number of significant digits is much enhanced. Four duodecimal digits possess twice the accuracy of four decimal digits; six possess three times the accuracy; nine possess five times the accuracy. This means twice the accuracy, for a given effort, in all engineering calculations, and from three to five times the accuracy in geodetic, astronomical, and physical work making use of logarithms.

11. The industrial and commercial world has already emphat-

---

* Dr. Mendenhall's reply to this, by quoting:

5½ yards........................	are 1 pole.
40 poles............................	" 1 furlong.
28 pounds..........................	" 1 quarter
30¼ square yards....................	" 1 square pole.
40 square poles	" 1 rood, etc.,

is irrelevant. Americans make no appreciable use of these units. Not one person in a thousand knows these tables.

ically pronounced in favor of division by twos and threes, and is daily voicing its corroboration of this opinion. The scientific world has emphatically pronounced itself, not in favor of division by tenths, but of harmony between mensuration and notation. Confronted by these two facts the discussion can turn upon only one pivot, viz.:—Shall the industrial and commercial world give up (in adopting the metric system) what it has shown that it cannot be forced, even by law, to do without, for the sake of granting to the scientific world what the latter very feebly desires? Shall the scientific world obtain its desired harmony between measures and notation (in the metric system enforced by law) by saddling upon the industrial world another system on top of and by the side of the one which it will not, cannot abandon? Or shall the scientific world gain its desired harmony between measures and notation, and at the same time gain much added facility, by conforming its notation to the duodecimal system of measures upon which the commercial world necessarily conducts its daily transactions?

12. It has been urged that the industrial world cannot change to the metric system because of enormous loss of investment in tools, etc. It is to be said in reply to this, with truth and force, that no mere value of investment, even if it be greater than the metric advocates urge that it is, can properly constrain so momentous a decision. But the question goes deeper than that. It is also true, on the other hand, that not even the boldest disregard of expense can hope to alter the inherent human preference for halves, thirds, and quarters over tenths; and no mere monetary gain, however imaginably great, could counterbalance the loss of human efficiency due to the repression of that preference, could it be accomplished.

13. On the other hand, the scientific world could change over from a decimal to a duodecimal system with greater ease than could any other portion of the human race make a similar change. Because

(I) It is intellectually the most flexible. I have tried the experiment of learning the duodecimal multiplication tables and of temporarily relying upon them and upon duodecimal notation for all computation. In spite of the inevitably frequent and disconcerting contact with the decimal system, in three days' time duodecimals were easier than decimals. I insist that it is easier to think in dozens than it is in tens. The tables for 2, 3, 4, 6, 8, and 9 in the duodecimal system are simplicity itself; only those for 2 and 5 in the decimal system can be compared with them. The obscure tables, where memorization alone can be of service, are 5 and 7 for the duodecimal system; the corresponding ones in the decimal system are 3, 4, 6, and 7, or twice as many. The tables for 8 and 9 in the decimal system and those for 10 and 11 (single digits) in the duodecimal occupy an intermediate position as to difficulty.

(II) The cost of replacing decimal tables, graduations, etc., in observatories and laboratories with duodecimal ones would be no greater, if nearly so great, as that of altering industrial tools, graduations, and tables from the present octonal or duodecimal to the decimal (metric) sytsem. When it is remembered that all astronomical work involves the cumbrous 60:1 division, for both arcs and for time, it is debatable whether, were the duodecimal logarithmic and other tables once in existence, observers would not find it worth while to translate observations from instruments where the graduations remained decimal into duodecimal records before computation, rather than to compute them in decimals.

14. The question, I repeat, is not one of possibility of change of systems, or of the cost of change. To avoid some change from the present intolerable confusion is impossible. On the other hand, the cost of any change whatever, commensurate with the needs of the situation, will be incalculable, in absolute units, and becomes greater each day. Only as a comparison between alternate methods can discussion of costs and gains be intelligent. Taken up in this way such discussion can lead to no other result than the choice of a duodecimal system of weights and measures harmonious with a duodecimal system of arithmetical notation.

15. There might be many such systems, any one of which would be better than any decimal system. To render the proposition concrete, however, the following suggestion of an outline for a system is offered.

Duodecimal Numbers.

The digits are to be those in use at present: 1, 2, 3, 4, 5, 6, 7, 8, and 9, with the addition of two new ones:

δ, or *dek*, having the value of decimal 10, and
ℰ, or *eln*, " " " 11.

Both of these characters can be readily and rapidly made with the pencil, in a form not to be confused with any of the other digits when carelessly made. The name *dek* is drawn from the Latin *decem ; eln* is an abbreviation of eleven. The form of dek (δ) recalls the idea of the decimal 10 with which the idea of that number of anything will be naturally associated by the present generation, until the duodecimal digits shall have become second nature by repeated use. The digit ε is similar to an E; thought of as the initial of " eln " its significance is easily kept in mind.

In place of the decimal point is used the duodecimal pair of points. This is in itself a gain. The former is too inconspicuous to be accurate. Continental practice uses the comma in preference, and frequently relies upon a different font of type for the fraction from that used for the integers, to minimize danger of error. When the duodecimal notation is used for financial purposes a more distinctive mark is necessary, to prevent fraud. A wavy vertical line, such as ⌇, or any similar mark, would suffice. In reading the following pages it will be important to note the presence or absence of this pair of points, distinguishing the duodecimal from the decimal systems of notation.

16. From these premises would arise the following notation:

NOTE.—The words outside the parentheses are the names of the duodecimal numbers; they are not to be considered as abbreviations, although they are phonetic abbreviations of the ideas which they are to convey and which are written out in full in the parentheses. Thus, the word "twodz" which is derived from "two dozen," is to be used exactly as the word "twenty," which is a corruption of "two tens," is used in the decimal system. The word "doz" is to be used as we now use the word "ten."

1	One.	20..	Twodz (two dozen).
2	Two.	21..	Twodz-one (two dozen and one).
3	Three.	22..	Twodz-two (two dozen and two).
4	Four.	29..	Twodz-nine (two dozen and nine).
5	Five.	2δ..	Twodz-dek (two dozen and dek).
6	Six.	2ε..	Twodz-eln (two dozen and eln).
7	Seven.	30..	Threedz (three dozen).
8	Eight.	31..	Threedz-one (three dozen and one).
9	Nine.	40..	Fourdz (four dozen).
δ	Dek.	50..	Fidze (five dozen).
ε	Eln.	60..	Sidz (six dozen).
10..	Doz.	70..	Sedz (seven dozen).
11..	Doz-one.	80..	Eighdz (eight dozen).
12..	Doz-two.	90..	Nidze (nine dozen).
13..	Doz-three.	δ0..	Dedz (dek dozen).
19..	Doz-nine.	ε0..	Endz (eln dozen).
1δ..	Doz-dek.	100..	One GROSS.
1ε..	Doz-eln.	1000..	One GREG (one great gross).

In fractions:

0.. 1 = one dozt (one dozenth).	½ = one-half = 0..6.
0.. 01 = one grost, or one groat.	⅓ = one-third = 0..4.
0..001 = one gregt or one gret.	¼ = one-quarter = 0..3.
= one divided by one great gross.	⅙ = one-sixth = 0..2
	⅛ = one-eighth = 0..16.

17. To attempt to handle this notation in terms of the familiar decimal system is, of course, cumbrous in the extreme. In handling duodecimal numbers one rule is fundamental and all-essential:

Think in Dozens! *

It is an existing fact, depending not at all upon suppositious future education, that the ordinary person can to-day think in dozens more easily than he can think in tens. The task in attaining familiarity with duodecimal numbers does not lie so much in learning the duodecimals as it does in forgetting the decimals. The difficulty is found, not in thinking in dozens, but in also writing and reading dozens duodecimally, after having for a lifetime performed the much harder task of thinking in dozens while writing and reading them decimally.

Duodecimal Multiplication-Table.

1	2	3	4	5	6	7	8	9	↊	↋	10..
2	4	6	8	↊	10..	12..	14..	16..	18..	1↊	20..
3	6	9	10..	13..	16..	19..	20..	23..	26..	29..	30..
4	8	10..	14..	18..	20..	24..	28..	30..	34..	38..	40..
5	↊	13..	18..	21..	26..	2↋..	34..	39..	42..	47..	50..
6	10..	16..	20..	26..	30..	36..	40..	46..	50..	56..	60..
7	12..	19..	24..	2↋..	36..	41..	48..	53..	5↊..	65..	70..
8	14..	20..	28..	34..	40..	48..	54..	60..	68..	74..	80..
9	16..	23..	30..	39..	46..	53..	60..	69..	76..	83..	90..
↊	18..	26..	34..	42..	50..	5↊..	68..	76..	84..	92..	↊0..
↋	1↊..	29..	38..	47..	56..	65..	74..	83..	92..	↊1..	↋0..
10..	20..	30..	40..	50..	60..	70..	80..	90..	↊0..	↋0..	100..

Duodecimal Weights and Measures.

18. To properly develop and advocate the duodecimal system of numbers would fill volumes. Enough has been said to furnish a notation for an illustrative duodecimal system of weights and measures and to show:

* Also think of 3, 4, 6, 8, and 9 as one-quarter, one-third, one-half, two-thirds, and three-quarters of a dozen respectively.

(1) How they would harmonize with each other;

(2) How they might be made to harmonize with existing units, tools, standards, habits, etc.

NOTE.—In the tables which follow, the names chosen for the new units are for illustrative purposes only. Probably much better substitutes could be devised

Linear Measure.

First and foremost, the *foot* and the *inch* could be retained. Their duodecimal expression would substitute for the inaccurate marks (′) and (″), or for the more accurate but more cumbrous substitutes, *ft.* and *in.*, simple integers for feet and a duodecimal fraction of a single digit for the inches, thus:

Decimal.	Duodecimal.
1′ 3″	1..3 ft.
2 ft. 7½ in.	2..76 ft.
5 ft. 3¾ in.	5..39 ft.

This could and would be done wherever feet and inches were more convenient than other units, quite parallel to and consistently with the adoption of the following suggestion; which is offered because the development of a complete duodecimal system from the foot as a basis does not result in all that could be desired.

19. The standard unit of length for all English-speaking peoples is the *yard.* Let it be retained as the base for the new duodecimal system of weights and measures quite as the metre is the base for the metric system.

The standard table of lengths would then become:

1 mile = 1000.. yards (= 1728 yards = 5184 feet).
1 yard = 10.. trinches (= one dozen 3-inch lengths).
1 trinch = 10.. quarters (= one dozen quarter-inch lengths).
1 quarter = 10..groats (one groat = one forty-eighth of an inch).

All of these units of length are familiar ones. They are all exact equivalents of present units except the new mile, which is 1.8 per cent. shorter than the present statute mile. But the statute mile is only one of half a dozen different ones, if all civilized countries be included. Thus the present nautical mile varies from 6,080 to 6,088 feet. Taking the average, the new system would stand:

1 nautical mile = 1,210.. yards.

Of the other units, the yard, the foot, and the inch would be used as at present, but with greater facility. The *trinch* (3 inches) would probably be little used as a unit of length; it fits popular needs as little as does the unit decimetre. The *quarter*, or quarter-inch, would probably become the standard unit for all shop-measurements. Very few machine dimensions would run so large as to make its numbers cumbrous, as is the case when the millimetre is used; very seldom, on the other hand, would

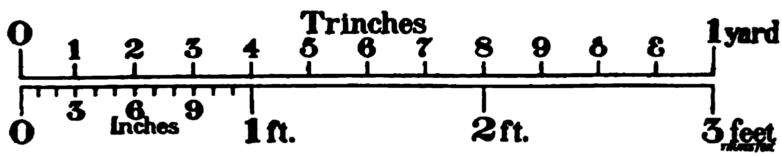


FIG. 52.

any need arise, on the larger work, for a division of it into fractions. When such need dild arise, on the smaller work, the standard of shop fractions: $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$ inch, etc., for which every workman carries his scale, could be used with perfect ease, as shown by the table below and by Figs. 52 and 53, by means of which he would make his translations by eye instead of by mental or written arithmetic.

The *groat* would take the place of the millimetre and the hundredth of an inch. It is closely equal to half a millimetre (0.52916 mm.).

20. In the machine-shop transition to the new system could

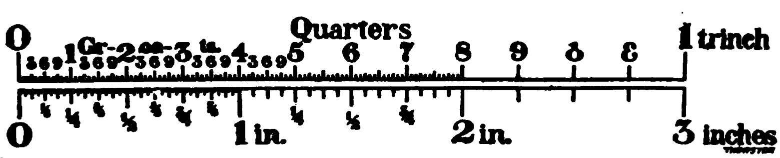


FIG. 53.—THE STANDARD 3-INCH STEEL SHOP-SCALE UNDER THE NEW SYSTEM.

be made without the slightest change or expense for new tools, etc., except for a new 3-inch steel scale graduated like Fig. 53 for each machinist. New patterns would naturally run on new habits of dimensioning; but old patterns could be produced with no interference whatever with the new. The only obstacle to the adoption of the new system would be the necessity for the learning of the duodecimal multiplication-table by each machinist, which could be done in three weeks of evenings.

The great bulk of machine-work relies upon units no smaller than $\frac{1}{16}$ inch. All such dimensions are expressible in quarters by a single duodecimal place. The same number of digits will express one-third of one-sixteenth, or one forty-eighth of an inch; which dimension would probably be used, in all future work, in place of the sixty-fourth, or one-fourth of a sixteenth, of an inch. Thirty-seconds and sixty-fourths require two duodecimal places. The same number of figures will express divisions to $\frac{1}{576}$, or one-ninth of one sixty-fourth of an inch.

On the other hand, two digits before the duodecimal points suffice to express any dimension short of a yard. The standard divisions on the scales now in use in the shop would be expressed as follows:

$\frac{1}{8}$	*inch*	= 0..6	*quarter.*		$\frac{7}{8}$	*inch*	= 3..6	*quarter.*
$\frac{1}{16}$	"	= 0..3	"		$\frac{5}{8}$	"	= 2..6	"
$\frac{1}{32}$	"	= 0..16	"		$\frac{5}{16}$	"	= 1..3	"
$\frac{1}{64}$	"	= 0..09	"		$\frac{5}{32}$	"	= 0..76	"
$\frac{1}{12}$	"	= 0..4	"		$\frac{5}{64}$	"	= 0..39	"
$\frac{1}{24}$	"	= 0..2	"		$\frac{7}{64}$	"	= 0..53	"
$\frac{1}{48}$	"	= 0..1	"		$\frac{9}{64}$	"	= 0..69	"
$\frac{3}{4}$	"	= 3..	"		$\frac{11}{64}$	"	= 0..83	"
$\frac{3}{8}$	"	= 1..6	"		$\frac{13}{64}$	"	= 0..99	"
$\frac{3}{16}$	"	= 0..9	"		$\frac{15}{64}$	"	= 0..ε3	"
$\frac{3}{32}$	"	= 0..46	"		$\frac{17}{64}$	"	= 1..09	"
$\frac{3}{64}$	"	= 0..23	"		$\frac{19}{64}$	"	= 1..23	" etc.

Until the duodecimal multiplication table is learned these figures seem more confusing than helpful. But even without that preparation, let any shop arithmetician sit down to these duodecimal fractions, *thinking only in dozens*, and trace their relations; he will finish with a strong first impression of the facility and convenience of duodecimals.

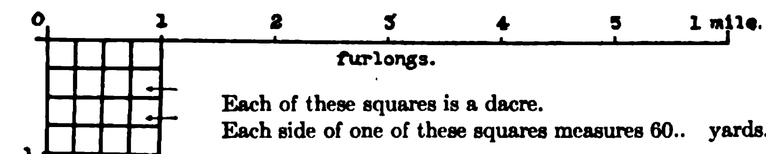
The duodecimal statement of these same fractions in terms of an inch is only slightly less clear and facile than the above. Thirty-seconds and sixty-fourths require three duodecimal places instead of two. It is finally to be remembered that these duodecimal expressions for the familiar vulgar fractions can be multiplied, divided, etc., more easily than can decimal fractions—when once the duodecimal multiplication table is learned.

Square Measure.

21. Of all of the tables of measure, square measure presents the most hopeless aspect to the American reformer. The trouble is, not that the system is incapable of reform, but that more finished

work lies recorded in it than in any other measure. The great bulk of the territory belonging to this government has been surveyed, divided, and sold by the square mile, section, quarter-section, and acre. To upset this work is a stupendous proposition. It is now more than thirty-six years since Congress adopted the metric system, including its land-measure, yet we hear less to-day of ares and hectares than we did then. On the other hand, the initiative in any change of measures must originate with the federal government. Should the nation once decide that change were imperative (which is the supposition upon which this paper is based), probably no portion of the task would find itself so unified in control and so quickly accomplished as the alteration of the government land records.

22. A duodecimal system based upon the yard naturally results in a system of square measure something like the following: *



Each of these squares is a dacre.
Each side of one of these squares measures 60.. yards.

TABLE.

1 square mile	= 6 furlongs square.
	= 30.. square furlongs (3 doz. furlongs).
	= 400.. dacres (4 gross of duodecimal acres).
	= 1,000,000.. square yards.
1 square furlong	= 4 dacres square.
	= 14.. dacres (one dozen and four dacres).
	= 40,000.. square yards.
1 dacre	= 60.. yards square (6 dozen yards square).
	= 3,000.. square yards (3 gr. gross of sq. yds).
1 square yard	= 100.. square trinches.
1 square trinch	= 100.. square quarters.
1 square quarter	= 100.. square groats.
1 squard yard	= 9 square feet.
1 square foot	= 14.. square trinches.
	= 100.. square inches (9 × 14.. = 100..).
1 square inch	= 14.. square quarters.
	= 1,400.. square groats.

* To appreciate the figures it must be remembered that, duodecimally, 4 squared = 1..4; that is, one dozen and four. Similarly, the square of 6 is 30.., or 3 dozen (threedz).

23. All of the above units larger than the yard depart sufficiently from the present units so that interchange would have to be formal and revolutionary. The duodecimal square mile is 3.7 per cent. smaller than the present square statute mile, the proposed linear furlong is 31 per cent., and the square furlong is 71 per cent. greater than at present, and the dacre is 7.1 per cent. greater, or has a side 3.5 per cent. longer, than the acre.*

Volumetric Measure.

24. The proposed duodecimal units of volume are the ***standard cubic yard***, the ***cubic trinch***, and the ***cubic quarter***.

TABLE.

1 cubic yard	= 1,000..	cubic trinches.
1 cubic trinch	= 1,000..	cubic quarters.
1 cubic quarter	= 1,000..	cubic groats.

1 cubic yard = 23.. (two dozen and three) cubic feet (23.. = the cube of 3).
1 cubic foot = 54.. (five dozen and four) cubic trinches (54.. = the cube of 4).
= 1,000.. cubic inches (23.. × 54.. = 1,000..)

For both dry and liquid measure the proposed duodecimal units are:

(I) The *trink*, or cubic trinch, a cube measuring 3 inches on an edge;

(II) The duodecimal *gallon* of 180.. (216) cubic inches, a cube measuring 6 inches on an edge. Thus:

---

* No idea of the simplicity of the above system can be gotten by a glance at these figures without having learned the duodecimal multiplication tables. Thus, to divide 3,000, one of the numbers of the table, by 14, another of them, were they both decimal numbers, would be cumbrous and would lead to an interminable fraction. But when both are duodecimals the task is one of short division, viz.:
14.. | 3,000..
230.. "Doz-four (one dozen and four, or one and one-third dozen) goes into threedz (three dozen) twice; carry four. Fourdz (four dozen) contains doz-four three times."

TABLE.

Dry Measure.	Liquid Measure.	
	1 hogshead	= 8 cubic feet (a cube 2 feet long on each edge).
		= 54.. gallons (54.. = the cube of 4).
		= 368.. trinks (368.. = the cube of 8).
	1 barrel	= 4 cubic feet (4 = 2 × 2 × 1).
		= 28.. gallons (28.. = 4 × 4 × 2).
		= 194.. trinks (194.. = 8 × 8 × 4).
1 bushel	= 8 gallons	= 1 CUBIC FOOT (= 2 gallons cubed).
	= 14.. quarts	= 54.. trinks (= 4 trinks cubed).
1 peck	= 2 gallons	= ½ cubic foot.
		= 8 quarts.
		= 14.. trinks.
4 quarts	= 1 gallon	= 8 trinks (a cube 6 inches long on each edge).
1 quart	= 1 quart	= 2 trinks (a rectangular solid 3″ × 3″ × 6″).
1 pint	= 1 trink	= 23.. cubic inches (a 3-inch cube).
		= 1,000.. cubic quarters.
		= 1,000,000.. cubic groats.

25. The proposed hogshead contains 64 (54..) of the proposed gallons, as against 63 present gallons in the present hogshead; but as the proposed gallons are 6½ per cent. smaller than the present United States standard gallon, the proposed new hogshead and barrel are 5 per cent. smaller than at present. The proposed new quart, bushel, and peck are also 6½ per cent. smaller than at present, and the trink is the same proportion smaller than the present pint. One trink = 0.44245 litre.

Measures of Weight.

26. The proposed duodecimal unit of weight is that of one trink, or cubic trinch, of distilled water at the temperature of maximum density. Such a cube would weigh 0.97538 pound, or about 2½ per cent. less than 1 pound avoirdupois. Let it be called a *poid*.

TABLE.

1 (new) ton	= the weight of one cubic yard of distilled water.
	= 1,000.. poids (one great gross of poids).
1 poid	= the weight of 1 3-inch cube of water.
	= 10.. *dozts* (dozenths of a poid, or duodecimal ounces).
1 dozt	= 10.. *parts* (duodecimal substitutes for the drachm).
1 part	= 10.. *gregts* or *grets* (of a pound).
	= 2 duodecimal pennyweights, (1 p'wt = 6 grets).
1 gret	= the weight of a quarter-inch cube of water.
	= 4 (new) grains.
	= 200.. pennyweights.
1 poid	= 1,000.. grets.
1 pint	= 4,000.. new grains.
	= 20.. (24) grains, as at present.

In this table the *dozt* is just 30 per cent. greater than the present avoirdupois ounce, or 21.5 per cent. greater than the Troy ounce; but as ounces are not a standard measure of weight, but are used solely as convenient fractions of a pound, this discrepancy matters little. The *part* is 19 per cent. less than the apothecaries' drachm. The proposed duodecimal pennyweight and the new grain are each just 1.27 per cent. greater than their existing standard counterparts. The proposed new ton is 15.7 per cent. less than the present short ton, or 24.8 per cent. smaller than, or almost exactly three-quarters of, the present long ton. Considering, however, that in addition to these two tons we already have in regular use several sizes of marine-registry tons, the miner's ton, and a few more such odd ones, not to mention the metric tonne, it hardly appears that there is an existing standard from which to depart. The convenience of having the ton the weight of a cubic yard of water far overbalances any objection to change from existing methods.

[In the presentation of the paper before the Society the author here refered to a wall-chart, electrotype of which is appended as Fig. 54, displaying the comparative amounts of work involved in calculating the cubic contents, in the several units of volume and weight, of a rectangular tank 24 feet $11\frac{3}{4}$ inches long by 21 feet $11\frac{3}{16}$ inches wide by 5 feet $2\frac{27}{64}$ inches deep, filled with water

The left-hand portion of the chart exhibits the present method, the right-hand the method by the proposed system. It was not urged that this problem was a typical or common one in engineering work; but its awkward association of large and small units in the dimensions brings out graphically the mental saving to be expected in all computation, which is the only argument in favor

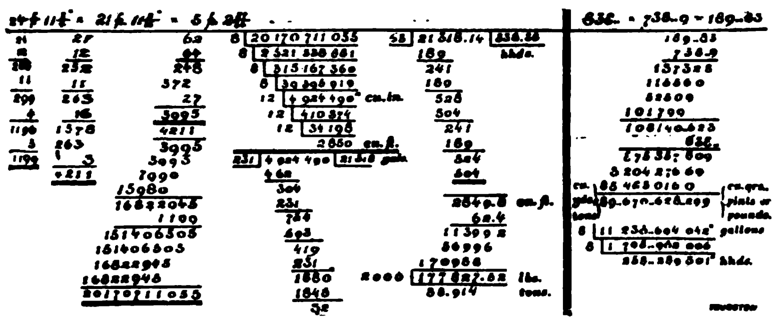


FIG. 54.

of the metric system which has been sufficiently cogent to insure its adoption, viz., in scientific work.]

Money.

27. If our arithmetical notation and our standard weights and measures unite in becoming purely duodecimal in character the monetary system is bound to follow. This proposition is not so revolutionary as would at first sight appear. The standard of value, the dollar, and all of its unit representations would remain unchanged. All bills of five dollars or higher denomination would naturally be called in and their equivalent issued in denominations of three, six, nine, doz, gross dollars, etc. But this process could be as gradual as desired. Under duodecimal notation five and ten-dollar bills would be inconvenient, but they would be useable.

As to coins, the half-dollar and quarter-dollar would remain unchanged. The dime, the nickel, and the cent would have to be retired. In their place would be issued fractional currency under the following plan:

1 dollar = 10.. bits (one dozen bits of 8⅓ cents value each).
1 bit = 10.. groats.
1 groat = 10.. grets (for purposes where the *mill* is now used).

The probable coins would be:

The silver half-dollar	= 6 bits	= 60..	groats	(= 50 cents);
The silver quarter-dollar	= 3 bits	= 30..	"	(= 25 ")
The silver *bit*	= 1 bit	= 10..	"	(= $8\frac{1}{3}$ ")
The nickel *half-bit*		= 6	"	(= $4\frac{1}{4}$ ")
The copper quarter-bit piece		= 3	"	(= $2\frac{1}{8}$ cents);
The copper *groat*				(= 0.7083 cents.)

28. Aside from its duodecimal advantages, this schedule presents two minor points of advantage over the present decimal one:

(I.) Change for a quarter could ordinarily be had in a single convenient denomination—that is, in three silver bits, whereas now it requires two denominations, dimes and nickels, to make it. (The practical objections to relying upon nickels alone for changing quarters are obvious.)

(II.) The progress of business toward finer margins and lower prices is steadily making the cent too large for many retail transactions. The smaller value of the groat harmonizes with this need.

29. But any complete comparison between the two systems must amount to the fact that we should never perceive any conscious difference in using the new system, although its economy of time and effort would be there nevertheless. The period of novelty due to its introduction would be less than that experienced by an American using British money for the first time.*

30. This completes the list of essential measures to be affected by the fancied revolution. From it will be plain that a line of progress is open before us which will accomplish the following results:

(*a*) Harmony between the systems of measures and of notation, which is *all* that the metric system has to offer;

---

* Therein is suggested another palpable opportunity for advance. The American five-dollar piece, the British pound sterling, the German twenty-mark piece, and the French 24-franc value ought to be made equivalents. Then we should have:

American.		British.		German.		French.
5 dollars	=	1 pound	=	20 marks	=	24 francs.
1 dollar	=	4 shillings	=	4 marks	=	4.80 f.
3 bits	=	1 shilling	=	1 mark	=	1.20 f.
1 bit	=	4 pence	=	....	=	40 c.
3 groats	=	1 penny	=	....	=	10 c.

(*b*) Greater facility in computation, which is what the scientific world especially desires;

(*c*) Division of units by twos and by threes, which is what the people especially desire, for they cannot live without it;

(*d*) A large measure of consistency with existing standards, it being absolute and accurate in linear measurements and so closely approximate in weights and measures of volume as not to appreciably disturb popular conceptions;

(*e*) Possibility of a gradual transition from one system to the other, not without great cost, but without catastrophe.

Thus, as to this last, all English-speaking peoples ought long ago to have united in making the standard gallon contain 216 cubic inches, or a cube measuring 6 inches on an edge. The standard pound ought to be the weight of a pint of distilled water at maximum density. The ton ought to be a cubic yard of the same. These changes can be undertaken to-day, to an advantage well worth any disturbance they might create, whether any duodecimal system of numbers be contemplated or not. And yet, when these things are once done it will appear that the bulk of the cost of the adoption of duodecimal notation, to the industrial world, at any rate, has already been overcome.

DISCUSSION.

Mr. John D. Riggs.—Our present system of feet and inches for linear measurement with inches divided into halves, quarters, eighths, sixteenths, thirty-seconds and sixty-fourths is just a little inconsistent. If we can compare a dimension of say a sixteenth of an inch with the inch as our unit, and get a clear conception of its magnitude, then why can we not compare the inch unit with a dimension of fifteen inches and avoid the use of the foot altogether? In practice does not a man come to know the value of a sixteenth of an inch as a unit, and should not this unit have a better name than it now has? When this unit gets the name that is due it the sixty-fourth can be read as a quarter of a sixteenth of an inch, and the millimetre will not seem so small when compared with this old unit with a new name.

The proposed system based on the number 12 seems to be very fortunate, in that it brings in the factor 3 just often enough to suggest a new unit-name, and thus avoid such fractions as thirty-seconds and sixty-fourths. But as the substitution 12 for 10 eliminates the objectionable feature of the metric system, why not base this system on the standard metre instead of the yard? Dividing the metre into 12 parts we get a unit about equal to the width of a school-boy's hand, and for the present we may call it a (metric) hand, dividing this again by 12 we get a dimension nearly equal to the diameter of the ordinary round lead-pencil, and which we may call a pencil. Dimensions smaller than this might be expressed as fractions.

Some will ask, why make a change to the metre and not get the metric system after all? But if in making this change we can anticipate the next one and thus make the two changes as one and avoid most of the confusion, we will have gained a point. If the second change should never be made by the other nations, we will still be based on the same standard, and our subdivisions will have a very simple relation to theirs.

After all, the thing we are after is, in my opinion, to be able to comprehend dimensions and measurements. That system is best which will enable designers and workmen to comprehend what stated dimensions represent.

Mr. George W. Colles.—This paper is something more than an admirable summing-up of the present status of the Weights and Measures question, and a step forward. It is a step forward in the right direction, and I can say with truth, that, of the scores and dozens of schemes for new weights and measures systems which have been proposed, and many, if not most, of which I have seen, this is the very first of which that can be said. I do not say it is the first "rational solution" of the problem, but is certainly the *most* rational solution that has yet been proposed, and therefore well deserves its title.

Some years ago, I had the honor to present to this Society a paper which, though bulky, was yet incomplete, for while part of the paper was devoted to the history of weights and measures, the remainder was devoted to the objections to the metric system, and having finished this part of the work, I found it necessary, on account of the magnitude of the work, to postpone a special consideration of the duodecimal system of weights and measures until another time. Nevertheless, as was pointed out in that paper, and as the title of the paper itself implies, the special consideration of the duodecimal system itself and its possibilities was merely postponed. The sequel to that paper which I then had in my mind and which I have had in my mind ever since, was to outline a scheme of improvement on precisely the same lines as that proposed by Professor Reeve. As I have never found an opportunity to undertake this myself, it is with very great pleasure that I see that it has been undertaken by some one else and at a critical juncture, because it is evident that, in order to stem the tide which has apparently set in favor of the metric system in many circles, it is necessary to give a serious consideration to our own present system, which is evidently capable of great amelioration.

As Professor Reeve has taken up the task and presented a rational scheme of improvement, I believe it will not be without interest to outline in a general way my own ideas on this subject, which were obtained largely during a consideration of the historical matter on the subject of weights and measures and which enabled me to arrive, though by a somewhat different path, at almost identical conclusions with his own. My investigation of past history shows that it is not the case that our present congeries of independent measuring units are in fact independent of one another, and merely selected at random without reference to their mutual relation. The fact that Professor Reeve has been enabled to work out so admirable and well-fitting a system from our present units has its *raison d'être* mainly in the fact that he has unconsciously returned to the original relations which these measures bore to each other. The mass of evidence on this point is very great, and could it all be presented together, would hardly fail to be convincing. While I speak at present wholly from memory, I think I can safely lay down the following as among the mutual relations of our weights and measures:

1. The gallon was 216 cubic inches, or one-eighth of a cubic foot. Our present gallon of 231 cubic inches is an anomaly, like all the rest, brought about by ill-advised legislation on a false basis.

2. The pint was a cube of three inches on an edge, or what Professor Reeve calls a "trink." It naturally follows that 8 pounds make a gallon, and 64 pounds or pints a cubic foot.

3. The bushel was 2,160 cubic inches (U. S. standard bushel = 2,150.48 cubic inches), that is to say, was 10 gallons, or $1\frac{1}{4}$ cubic feet. The *raison d'être* of the bushel is that it is an equivalent in weight of wheat to the gallon, that is to say, a bushel of *wheat* weighs approximately the same as a cubic foot of *water*,

or 64 pounds. Not exactly, perhaps; but the approximate ratio of 4:5 between the specific gravity of wheat and water (or rather wheat and wine, the two chief articles of commerce) was so convenient for ordinary measurements, that it was adopted here as in a number of other cases, some of which were referred to in my paper before mentioned.

4. It should be remarked that there was at some time a special measure of one cubic foot for liquids, though what it was called at various periods is uncertain. It was called *amphora* by the Romans and was the universal measure of capacity in bulk, as, for instance, in measuring the displacement of ships.

5. The *ton* (formerly the same as *tun*) was formed by doubling and redoubling upwards from the gallon, forming the intermediate measures of the barrel and hogshead, and the ton, therefore, was 32 cubic feet (*not* one cubic yard), or $2^{11} = 2,048$ pounds (or pints). The figure 2,000 is a corruption assumed for convenience in calculation by the decimal system, but it spoils the harmony of the original system.

6. The *mile* as a lineal measure is an anomaly, and not a part of the original system, being, as its name denotes, "mille passus," *i.e.*, one thousand double paces of five feet each, therefore partly founded on an independent base (the natural pace) and partly on the decimal system.

7. Neither does it appear that the *yard* is a part of the original system, but this was a Teutonic measure which was grafted on subsequently. Therefore, so far as concerns Professor Reeve's coincidences in duodecimals between the yard, mile, and quarter inch, they are purely accidental. The *foot* was the actual standard of the ancient system as it is in all civilized countries to-day, while the yard or its equivalent is limited to a few, and has but comparatively limited application. The foot is still used to the exclusion of the yard in the great majority of cases, and has been from the first divided into 12 inches, 144 lines and 1,728 points —therefore strictly on the duodecimal system.

8. The above considerations are sufficient at least to show that the units of the ancient metrological system were strictly co-ordinate one with another, although the subdivisions and multiples of these units were not strictly duodecimal, but on the contrary partly duodecimal and partly octonary. Most of these points are referred to incidentally in my paper before mentioned.

While I have no thought of the desirability of returning to a system merely because it is ancient, still it is my firm belief that it will prove far easier to return to the original system than to undertake a new departure to exhibit relations between units which are entirely foreign to it and merely accidental.

It appears also from this standpoint, that while Professor Reeve is strictly correct in saying that we should long ago have adopted a standard gallon containing 216 cubic inches, he falls into error in making a *bushel* equal to one cubic foot, or 8 gallons, instead of 1¼ cubic feet, or 10 gallons, which it approximately is, and which would amount to an extremely small and comparatively unnoticeable departure from the present bushel, and consequently also in its subdivisions. Professor Reeve is, of course, welcome to retain the cubic foot as a dry measure, but he must not call it a bushel. Similarly the proposal to call a measure of 1,728 pounds a *ton* not only does unjustifiable violence to the proper relations (with respect to which a 2,000-pound ton is much more proper), but he also departs far too widely from our present ton to avoid an intolerable confusion. There is no ton now of less than 2,000 pounds, and while a measure equal to three-quarters of the present long ton or metric ton may be convenient, it must not be called a ton.

Perhaps I may be permitted to add to the already very excellent setting-forth of the matter in Professor Reeve's paper a few general considerations on the question of altering weights and measures.

1. The first question to be considered, when a proposal for metric reform is made, is, shall we sweep away altogether the old units and replace by new ones, or shall we amend and improve the old system? And in so amending, is it better to retain only the basic units for the different quantities, or shall we make small and insignificant changes as far as possible in the special subdivisions, so that they shall accord with one another on the system we propose? Experience shows the difficulty, nay almost impossibility and worse than uselessness of attempting the first course. The very first principle to be laid down is to adopt the very fewest new units possible, and the second is that, where they are adopted, they must be commensurate with the old. As to making small changes in secondary units and calling the changed units by the same names, great objections have been offered owing to the confusion necessarily engendered as to exactly what is meant by a name, yet, on the whole, I think this

is far less an evil than the introduction of an absolutely new and discordant system, and far less dangerous than the introduction even of new units which accord more or less with the existing ones.

2. Not less a point for consideration is that the proposed reform must be capable of being adopted gradually, little by little and piece by piece, and not by any sudden and revolutionary change, of which the metric system is a perfect example, and which has the result of merely introducing discord, which it *never* replaces or drives out. Now Professor Reeve's plan is just such a system as, contrary to the metric system, may be adopted little by little and with the least possible violence to popular uses and customs, though undoubtedly requiring the aid of a certain amount of legislation. It is not by any means necessary that it should *all* be adopted to secure the improvement of the present system, but the adoption of any part by itself will improve the system, leaving the question of the adoption of a further part optional at any time in the future. Nor is it necessary that all the proposed units be adopted precisely as outlined by Professor Reeve; but this should be the subject of consideration by a commission of highly-skilled metrologists of the principal English-speaking nations before anything is done, if that be possible; although I do not mean to say I would disfavor a single well-considered step by the United States Government alone, as international commissions are so seldom fruitful of results.

3. As to the proposed duodecimal notation, I must admit that is a question I have never seriously considered. Such a system has been proposed before by many mathematicians and even actually used. That it is actually easier when once learned is beyond a doubt, and yet it is equally true and more important to note that the decimal system is so deeply and universally rooted in the mind of man, that it would be nearly impossible to eradicate. I feel that, while scientists may use this to advantage if they do not come into contact with the decimal system, yet the latter would introduce such confusion in their thoughts, that they would find themselves perforce compelled to abandon the former. It seems to me, in fact, that even Professor Reeve has underrated the difficulties of making a change, as history proves that people hold on to their units with a firmness that nothing can shake, albeit such firmness is nothing after all but a mere

dead resistance of a magnitude practically insuperable by the legislator.

4. As to money, our present unit has, of course, no actual relation whatever to any metrological system, old or new. Professor Reeve's division of the dollar is therefore purely arbitrary and in so far objectionable; although that it would be more convenient than the present, goes, of course, without saying. A good instance, however, of the point last referred to, as to the difficulty of changing units, is that suggested by him in the *approximate* equivalents of the American half-eagle, the British pound, the German 20-mark piece, and the French 24-franc value, which, of course, by all common sense ideas, *ought* to have been unified long ago, but, as a matter of fact, this has been tried and given up as a hopeless task, as no agreement between the different nations concerned could be reached. The British nation, for instance, would undoubtedly be very glad to have the United States, Germany and France, change *their* units to correspond with the pound sterling, but they themselves would not be willing to change the value of the pound by the twentieth part of one poor scruple, as has been shown by the agitation for decimal currency and on other occasions in Great Britain. As well might it be tried to agree upon a common language.

5. One of the greatest objections to the system proposed, not only of duodecimal notation but of duodecimal weights and measures, is the introduction of new words. The experience with the metric system showed what an insuperable prejudice the popular mind has to such innovations. This must be counted among the apparently unavoidable accompaniments of any important change in weights and measures.

In conclusion let me say that I do not think this question should be treated lightly or apathetically. There is no valid reason why the Committee on Coinage, Weights and Measures of Congress should continue to grind out, year after year, the same old bulletins and the same weather-worn arguments in favor of the metric system, and bills to make it compulsory. Could sufficient interest be aroused on the *other* side of the question, and this Committee be got to even consider the amendment of our present system in a rational manner, there is at least no doubt but that a much greater advantage would accrue to the public. The fact that hundreds of men, clubs, societies and other bodies can be got to endorse the metric system in a general way, or to cite points in its favor, as in the recent symposium called for by the Franklin Institute, seems at first disheartening to those of us who believe we see its defects; yet they are in fact of little more importance than the popular endorsement of a patent medicine, because very few of such persons as have endorsed it, however able in their special department in life, have ever given the question of weights and measures and notation a serious and prolonged consideration. The fact that they cite the decimal divisions as the great advantage of the metric system, whereas in fact, they are the supreme objection to it, shows fairly well that this is the case. I only wish that more of our practical scientists could be got to try the duodecimal system, especially with its accompanying notation, as Professor Reeve has done.

Mr. H. H. Suplee.—In the first place I wish to congratulate Professor Reeve on the good work that he has done. I think the applause which greeted him showed that many of the audience agreed in some of his points, at least. The only remark I wish to make now is to call attention to the fact that a somewhat similar system was prepared a number of years ago by the veteran John W. Nystrom, only that he based his upon 16 instead of upon 12. The system was worked out at short length in his well-known "Engineers's Pocket Book," although I believe it has been left out of the recent editions, and I think he prepared a complete arithmetic on that system and also used it in his treatise on "Steam Engineering." I think his work in that direction was brought to a close by his death rather from any change of opinion on his part. He continued to be an advocate of it to the end, and I think that Professor Reeve has taken up that branch of the work in an excellent manner, and I hope will carry it through.

So far as the workman in the shop is concerned, it does not matter very much what system he uses, since he must work mainly to gauges anyhow. The dimension for him is, and should be, merely the name for the gauge, whether it is in the decimal or duodecimal system is a matter of minor importance.

Professor Reeve.—I should like to know a little more definitely than I have yet discovered what is the verdict of the Society upon this proposition. To make it of any value to the profession it must be raised from the level of a suggestion, where it now stands, to a condition where it can be tried, upon a limited scale at least. That means a large amount of decidedly tedious labor. I have had no time to undertake that. I have had no basis. I do not feel that I now have any basis for doing it. If there is no general opinion upon the part of the profession that progress in this line is valuable as well as possible, it is hardly worth either my while or that of any one else to prepare those tabulations of a numerical sort which are essential to the first trial of the plan. I will not say that I shall not some day undertake the task, but I certainly shall not do it immediately, and I should feel very little like looking forward to it if there is no general expression of approval. I would ask, rather as a personal favor, that there be either approval or disapproval in so far as there can be.

Mr. Wilfred Lewis.—I would like to ask Professor Reeve whether he could not give us a comparative statement of the relative merits of this system which he proposes on the system referred to by Mr. Suplee, in which 16 was taken as a base instead of 12—whether there are not advantages in favor of 16 which do not apply to the duodecimal system?

Professor Reeve.—The reply is simply that the history of the world, as Herbert Spencer puts it, has shown, by the survival of the fittest, that when a man wishes to divide a thing he first divides it by 2. If the division by 2 results in too large a quantity, he next divides by 3. If the division by 3 results in too large a quantity, he divides by 4. By that time the point where simple, easy division is carried on by the eye or by estimate has been surpassed. Beyond that it does not make much difference whether divisions run by 5, 6 or 7, or what they are; but to leave out the factor 3 would cut us off from two things: in the first place a very valuable division, smaller than a half and larger than a quarter, and which appears very prominently in this multiplication-table when you come to analyze it. That is the 3d; or 4 units on the basis of 2 parts. Secondly, we have got to adhere to present standard units of length. I think that nearly all of us are agreed on that, and the present standard of length is the foot and the inch. The factor 3 enters in everywhere until we subdivide the inch; then only do we adhere to the binary division. At any rate, the foot and the inch and the yard are inseparably connected with the factor 3.

Mr. F. A. Halsey.—I woud like to ask Professor Reeve regarding the feasibility of using the two systems conjointly through a long period of time, for therein, it seems to me, is the fundamental difficulty. I do not suppose there is any one who has given this subject any serious attention who is not convinced of the advantages of the duodecimal system. I suppose the actual, tangible advantages of that system compared with the imaginary advantages of the metric system would stand in the ratio of possibly 100 to 1, certainly 10 to 1. I think that Professor Reeve makes the same mistake as the metric advocates in assuming the chief difficulty to lie in learning to think in the new system. It seems to me that the chief difficulty lies in the fact that our system of notation, like our system of weights and measures, is "tied irrevocably to the past." What I mean is that our numerical records of all kinds, regardless of nationality, geography, language or age, are all based upon the number 10, and it seems to me that to introduce this change would introduce confusion that would last for a thousand years. That would be the case, unless the two systems could be used conjointly.

Professor Reeve.—In reply to that I would say that I anticipate that at the start, certainly, and for a long time probably, they would be used conjointly. The place where they would be used first would be the drafting-room. Draftsmen are slaves anyway, and they would have to adopt the system if they were told to do so. If the drawings had to be labeled in duodecimal units, then the draftsmen would soon find it most convenient to compute in duodecimals; but I can easily imagine a drafting-room in which the men are not required to do that; in other words, where they would use decimals for the attainment of these duodecimals, until they found it easier to do the opposite. For instance, they would say: "Seven times 8 is 56, and 56 is 4 dozen and 8;" they would then put down the 4 and the 8. They would continue to do that until they got tired of doing it, finding it easier, as I very promptly did, to think in dozens and to say: "Seven times 8 is 4 dozen and 8," as mechanically as one now says, "7 times 8 are 56."

In the shop the transition would be much more gradual. The machinist needs to know very little about any change in units. He uses exactly the same units, the same gauges, he uses the same dimensions in everything. He uses this lower side of his rule (pointing to the lower scale of Fig. 53) which he now uses, just as long as he finds it easier than to use the upper scale.

When the shop-drawings come in with a dimension stated in the new units, he picks it out by reading 3, 6, 9, etc., on the new scale, except that the new scale is simpler. At the end of this process he finds that he has arrived at one of his old-fashioned, familiar dimensions. When he finds it easier to work to 3, 6, 9 directly, without translation into the old scale, he will do it; but he can do either. Any man in the shop, as I imagine it, can take his choice between the duodecimal way of handling the old measures, or the old way of handling the old measures, whichever way is the easier. I do not anticipate the new unit becoming in any way a fixed standard. Men would probably slowly acquire the habit of thinking in quarter inches instead of thinking in inches, but in the meantime the length would be the same and the tool would be the same. The 3-inch length I do not anticipate becoming active in shop-measurements, except in one way: Tapers are always stated as so much to the foot. In the new combined scale those ratios may appear and be used either as inches to the foot, as in the old-fashioned scale, or as trinches to the yard, or as quarter inches to the trinch. The taper may be marked off and set in sixteenths or in these new marks, or in any other way. The lengths are the same, the proportions are the same.

The transition to better methods by any duplication of systems will undoubtedly bring in confusion and error; but duplication is absolutely unavoidable if any progress is to be made. It seems to me that the confusion and error in the method proposed would be exceedingly small. In other words, the price paid would be exceedingly small, as compared with any other possible outlook away from the present system.

Mr. Halsey.—I asked the question in the sense of numerical calculations and records rather than in the sense of measurements. Imagine a bookkeeper to have made the change in his books. How much confusion would result from his references to the old books in the old system, from his constant receipt of bills, price lists, etc., from those who had not made the change, and from the necessity of his making out bills in the old system for those who could not read them if made out in the new. It seems to me that for a long period of time we must all have an equal facility in the use of both systems, and that, unless this is possible, the change is impossible.

Mr. Reeve.—In the dollars it would make no difference whatever. In the cents it would. He would have to translate the cents.

Mr. Halsey.—Do you rely upon the double decimal point to distinguish in which system a sum of money is expressed?

Professor Reeve.—Not in monetary transactions; I would not. A man could then easily raise his check by simply putting on a double decimal point. But it is easy to substitute a mark in monetary transactions which could not so easily be changed. But where the two duodecimal points were relied upon I see no probability of greater error therefrom than now occurs from reliance upon a single decimal point.

As for other computations, the man in the drafting-room chooses either side of the chart (Fig. 54). He can compute in the old measures and simply translate his final result into the new one, which is a compromise process; or he can accept the new system and calculate by the method shown on the right-hand side of the sheet. Of course, while he is taking his choice and using both systems at once, there will be a number of mistakes. I might say, however, that in preparing that chart, which was prepared rather hurriedly, the first computation developed three mistakes; but they were all on the old system, on the left-hand side of the line. While carrying out the duodecimal multiplication at the same time that I was handling the decimal numbers, as you see, there was no mistake in the duodecimal multiplication. Within the first week that you try half a dozen times, half an hour at a time, to multiply and divide duodecimals, you will realize that it is very much easier to think in dozens than in tens. It is easier and more accurate. You will have to take my word for that.

Mr. McGill.—I would like to ask Professor Reeve how he would change that scale (Fig. 53) into thousandths? There are lots of us who do not use 64ths, not once in a week, as a rule.

Professor Reeve.—The thousandth seems to be a unit by itself. Whenever the machinist works to a thousandth he does not stop at a thousandth. It is not accurate enough for that kind of work, and when he needs a fraction of a thousandth that fraction is not a ten-thousandth. He does not work to so many thousandths and then three ten-thousandths over, for instance. He works to so many thousandths, half-thousandths, or quarter-thousandths. The words "a thousandth" is a unit. So long as that unit is used I do not think that there would be any particular benefit in trying to translate it into the new system. If the drawings were stated in that way and the gauges were made in that way, they would be used in that way. In screw-threads there would be no change whatever. They are stated so many per inch. The inch we can handle as well in this new system as we do now. The new substitute for the thousandth of an inch, as new drawings come in, would be found in the second duodecimal place, considering the quarter-inch as the standard unit. The second duodecimal place beyond the quarter-inch is $\frac{1}{144}$ of a quarter-inch, or $\frac{1}{576}$ of an inch, or one-ninth of a sixty-fourth (see Fig. 53). Now the 576th of an inch is accurate enough for nearly all fine work—not so fine as to need fractions of a thousandth—and you get that degree of accuracy with no more figures than are needed to express either thirty-seconds or sixteenths. But if greater accuracy be needed, the use of another, or third, duodecimal place permits the expression of dimensions as fine as one-twelfth of the 576th just mentioned, or about seven times as fine as the thousandth of an inch; and I think it will be admitted that very little machine-shop work goes any finer than that. Moreover, to remind one of how frequently the advantages of duodecimal notation crop out, if a man had been working to the second duodecimal place from the quarter-inch, either in shop or drafting-room, and finds that he needs greater fineness, he is not compelled to either limit himself to halves or fifths, as he is in using thousandths, or else add a vulgar fraction on the end of a long decimal fraction; instead, the third duodecimal place permits him to work to halves, thirds, quarters or sixths of his last smallest unit without incurring vulgar fractions. So that in a shop where thousandths were used the new system would offer a more convenient parallel which would soon drive the other out. But in so far and so long as thousandths were used I should not contemplate any attempt at handling them on the new system. They simply would gradually die out of use.

Mr. Colles' * suggested idea that the coincidences with existing units of weight and volume which developed from the foundation of a duodecimal system upon the existing units of length was something more than a coincidence, had already impressed itself upon the author during his investigation of the question, and had been orally discussed with some of his friends.

*Author's closure, under the Rules.

But the argument to be drawn therefrom did not seem to be sufficiently defined or cogent to warrant its inclusion in the paper. It is nevertheless of great interest, and Mr. Colles' able presentation of it from the historical standpoint is valuable.

As to the author's suggestions regarding a new bushel, or similar new modfications of old units, as of the new names suggested for the numerals, they were included merely as illustrations, to render the proposition concrete. In approaching this entire subject one cannot avoid being impressed with the utter futility of attempting to accomplish any real progress by proving by argument that any particular system is so good that every one ought to adopt it. The only proposition which can attain universal adoption is one so simple and concrete, carrying such patent advantages, that each individual who meets it may adopt it with profit, without waiting for others to realize its advantages. Such a proposition is that for dividing the 3-inch scale duodecimally and using corresponding duodecimal arithmetic in the drafting-room—or such a proposition it would be were the necessary accessories in shape to be laid before the Society or the public. They could be produced at much less cost of effort and money than has already been expended upon many similar projects which failed. But until they are produced the topic must remain in the form of a suggestion only. But in such a suggestion it is not only proper, it is necessary, to point out that the adoption of the first few steps, for the sake of their immediate convenience, would not land the pioneer at a dead-end, out of touch with other systems and unable to keep near his fellows without retracing his steps, but would open before him additional opportunities for convenient modification of existing units into consonance with what he had already done, when he felt that they, too, offered advantages fit to warrant the change.

Thus, as to the new ton, if it be supposed that duodecimal notation has been adopted within a certain community (which might consist of a single shop or circle of shops, such as this country now has several of), the alternative lies before it of either calling the present short ton 1,138.. (= 2,000) lbs., and the present long ton 1,368.. (= 2,240) lbs., or of making use of the duodecimal 1,000.. lbs. as a new unit. So long as outsiders using the old system are in the majority, it will pay to do the first, translating from decimal to duodecimal numbers by the translation-tables which must be relied upon so long as both systems are in use. Finally, however, it must prove to be more convenient to use the 1,000..-lb unit, and for it then will be found a name. Whether this unit be smaller or larger than what would seem to be an ideal size for a ton will have nothing to do with the final result.

As to the author's suggestion as to what abbreviations of the duodecimal, or "dozenal," numbers might be the result of long use, he would say that he has already found reason to regret having made it. The non-technical, and to a certain extent the technical, press has seized upon these strange names as constituting the core of the idea. The author, in what use he has made of duodecimal numbers, has never found reason to depart from the simple names of "four dozen and eight," etc. They carry an already familiar idea in an only slightly strange manner, and are very readily adopted and understood.

No. 963.*

CENTRIFUGAL MACHINES AND THEIR USES.

BY BARTHOLOMEW VIOLA, BROOKLYN, N. Y.
(Member of the Society.)

1. The author does not wish to consider the theoretical part of these machines, but to describe the main construction and the details as used at the present time. The familiar principle of centrifugal force of rotating masses is used for the purpose of separating juices, liquids, etc., from solids, and also to separate liquids of different specific gravities from each other, or to clarify dull liquids by separating from them the contained inert matter. When such mixtures are placed in a drum or kettle, and rotated rapidly, every particle will, of course, tend to move outward with a force expressed by the well-known formula $C = w^2 W r$, which indicates that the force is proportional to the squares of the angular velocity and the distance from the axis of rotation, and also to the weight of the respective substances. Consequently fluids will escape from the drum if there is opportunity and solids will remain.

2. The case of removing moisture from fabrics is very simple, as the material may be wound about an axis and fastened by a cord, so that while the moisture will fly off from the swift rotation, the web will be held. For the separation of uncompacted masses, such as rough sugar or chemical crystals, a drum-shaped vessel open at the top, and manufactured of the best steel, brass, or bronze, with holes in the cylindrical walls, is usually used, the axis of the drum being set vertical. When rotated the liquid will pass through the holes and flow down on the inner surface of an outside containing shell, whence it may be collected. For filtering impure liquids, the basket is lined with some porous material, which will allow the liquid to pass through but hold back the solid

* Presented at the New York meeting (December, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

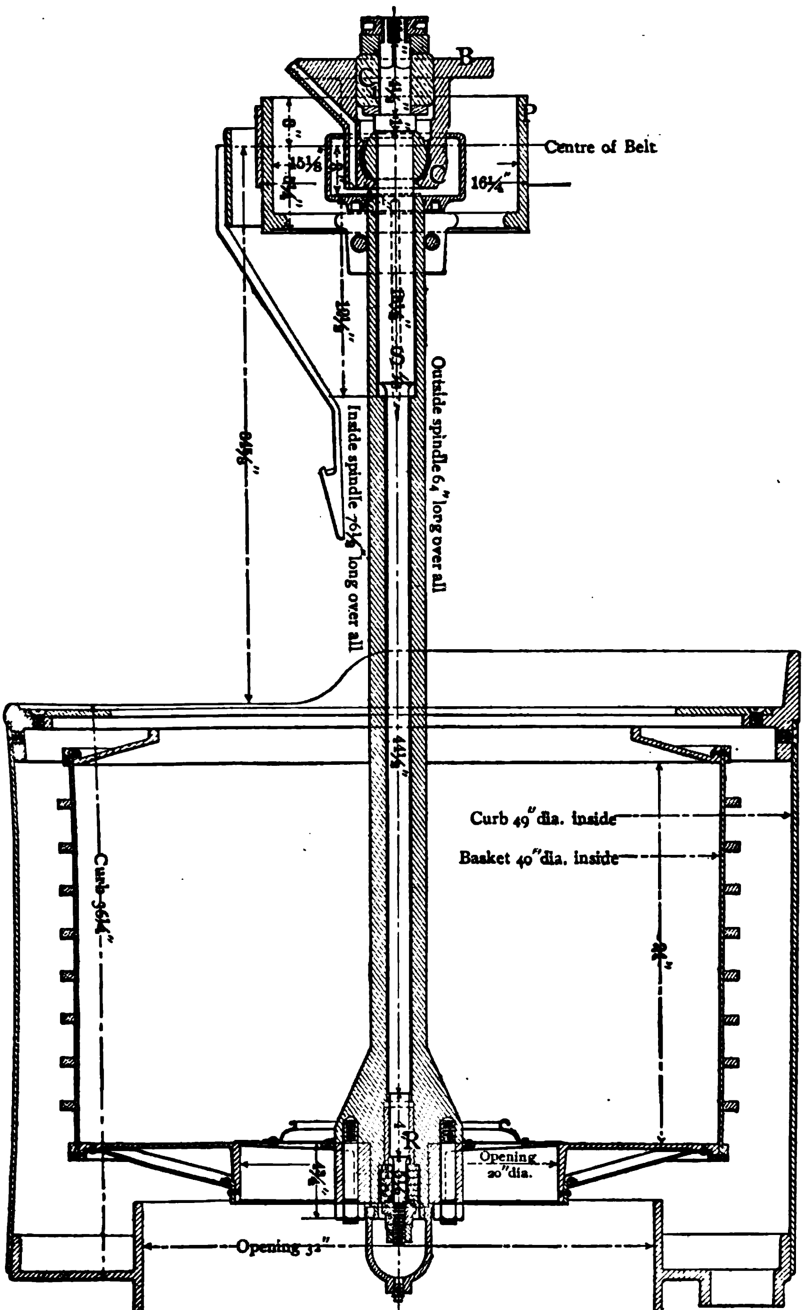

B
Centre of Belt
16¼"
Outside spindle 64" long over all
Inside spindle 76⅛" long over all
Curb 49" dia. inside
Basket 40" dia. inside
Curb 36¼"
Opening 20" dia.
Opening 32"
R

FIG. 55.

particles, but this method of filtering is little used, as the porous material soon clogs and has to be renewed.

3. Driving is usually accomplished by a belt or direct-coupled motor, and may be arranged either above or below the basket.

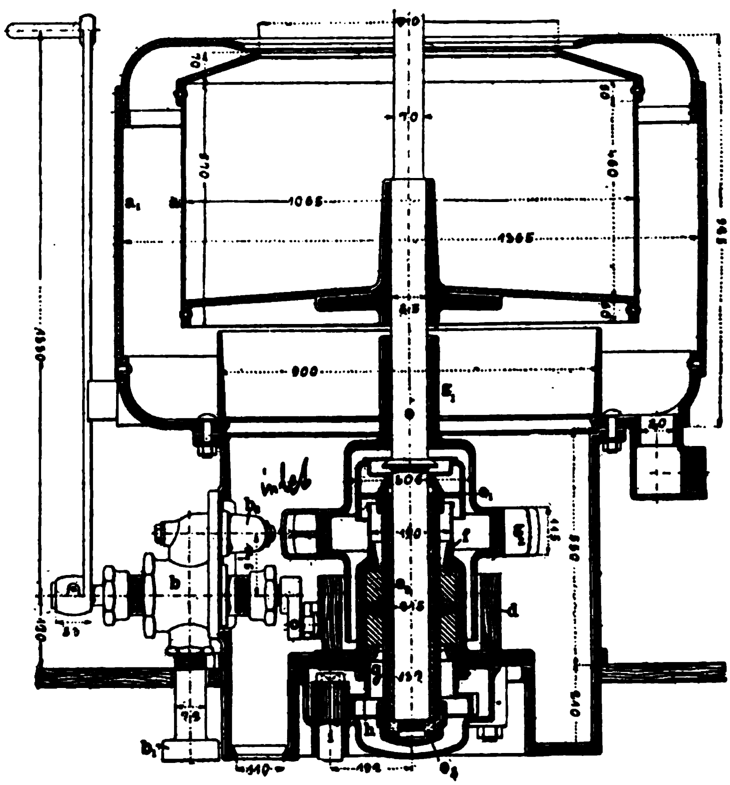


FIG. 56.

In those where the driving mechanism is above the basket, there is always a possibility that oil may drop in and contaminate the material, but it is usually a more convenient form to arrange. A strong brake should always be provided for stopping quickly, and the basket should be strongly mounted and carefully balanced so that the centre of gravity may always be in the axis of rotation. If this is not the case the vibration would soon destroy the whole machine, and the same result may be produced if materials are centrifugated, which will not form a homogeneous layer of even thickness on the inside of the basket. The speed of the machine generally depends on the size of the basket and on the material to be separated. A light basket can be run at a higher speed than a heavy one, and in general a basket 24 inches in diameter, carrying a load of 170 pounds, can run safely at 1,500 revolutions per minute, while one 60 inches in diameter, and with a load of 1,000 pounds, can only make 600 revolutions.

4. The typical construction for American and English machines is of the Weston system, over and under-driven types being shown in Figs, 55 and 56. In both forms the principle of the re-

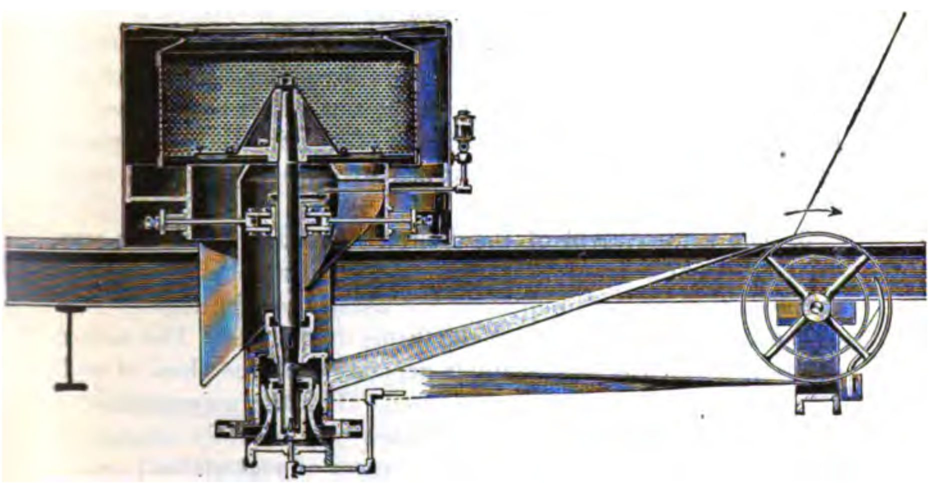


FIG. 57.

volving pendulum is used, the basket being allowed to oscillate within certain limits, thus balancing itself and reducing the power required to drive the machine to a minimum amount. In the European machines of Fig. 57 the axis is supported by a spherical bearing, so that the entire machine can accommodate itself like a spinning top, but is held from too violent motion by a collar bearing provided with a rubber buffer and tension rod.

5. The construction of the most important part of a self-balancing centrifugal machine, the Weston spindle, is shown in Fig. 55, *B* is a strong bracket or block, bolted to the overhead beam; *C* is a spherical bearing resting upon the block *B*, and in turn supporting the steel spindle *S*; on the upper end of the spindle is a rubber buffer, C_1, held in place lightly by a nut on the upper end; at the bottom is a special form of step-bearing, *R*, which

carries the outside revolving spindle. The pulley P is fixed upon the outer spindle, and the lower part forms the brake block, while at the bottom of the outer spindle is a flange which carries the basket. The hollow portion of the outer spindle serves as an oil chamber, so that the bearing R runs in a bath of oil, which is drawn out when necessary by means of a plug at the bottom.

Fig. 56 illustrates the Weston spindle for an under-driven machine, and at the same time shows the arrangement when water power is used, as the driving is done by a Pelton wheel, g_2. The india-rubber buffers are used to allow the spindle to swing slightly, and thus conform its centre of gravity to its centre of rotation. These spindles require periodical adjustment and tightening, which has often been a laborious task, involving the dismantling of the machine in order to get at the nut which compresses the buffer on the top. With the new type of machine the nut is placed below the buffer at g, and is turned by a small pinion, i, which gears with a flange on the nut.

6. The arrangement of the Pelton wheel for the latest over-driven type of machine is shown in Fig. 58, which, however, has recently been altered by placing the nozzles to 180 degrees from each other in order to balance the thrust of the jets. The method of driving which is most suitable depends upon the class of work for which the machine is to be used. For the manufacture of fine sugars and similar uses the basket may be fully charged at full speed, and will give a uniform fitness of material all around the basket; but if coarse or low-grade materials are to be handled, the speed must be gradually attained, three or four minutes being taken in reaching maximum velocity, because either the charge will not distribute itself evenly, or with low sugars, which are heavier than the molasses or liquors which it is desired to remove, the solid part of the charge will pack against the outside of the basket, and the liquids will have great difficulty in passing through. By coming to speed gradually the liquors will begin at once to leave the basket, and will thus keep the wall porous. For the former class of work, therefore, belt driving from a main shaft will answer admirably, but for the latter some form of individual motor, such as the water wheel of Fig. 56, the direct-coupled engine of Fig. 5, or the belted engine of Fig. 60 should be used.

7. European machines are largely of the under-driven type, and the best were those of Albert Fesca or Fesca's principles, such as shown in Fig. 57. It is plain that a properly constructed centrifu-

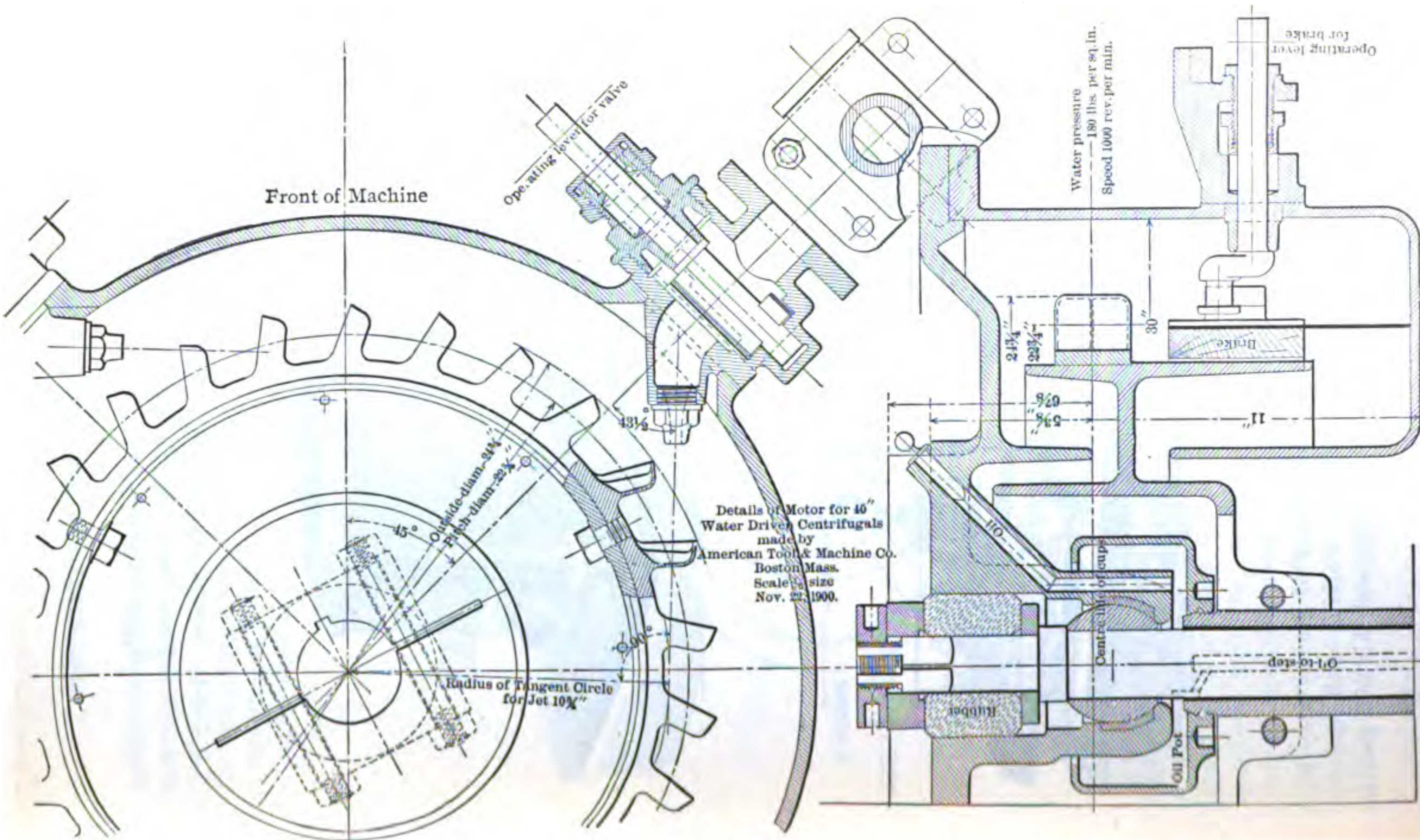

Front of Machine
Operating lever for valve
Details of Motor for 40"
Water Driven Centrifugals
made by
American Tool & Machine Co.
Boston, Mass.
Nov. 22, 1900.
Radius of Tangent Circle
45°
90°
30"
11"
Water pressure
180 lbs. per sq. in.
Speed 1000 rev. per min.
Operating lever
for brake
Brake
Oil
Centre line of cups
Rubber
Oil Pot
Oil to step

Fig. 58

gal machine should be so balanced that there will be no pull on the axis or on the support in consequence of the rotation, and that the only side thrust will be due to the motive power. Even if a ma-

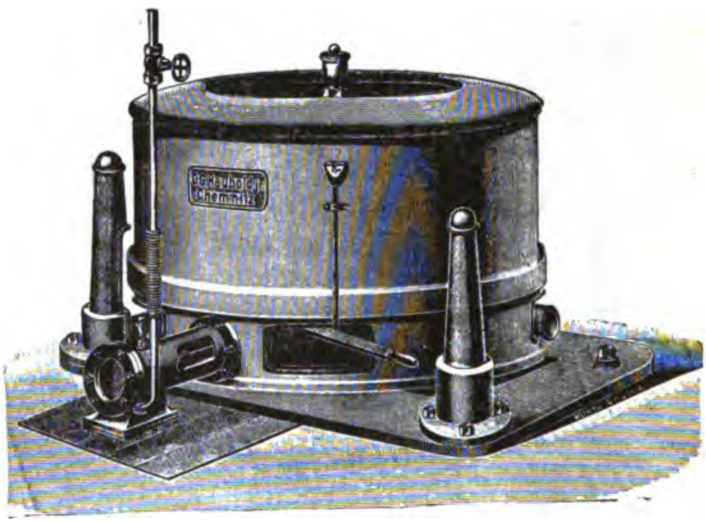


Fig. 59.

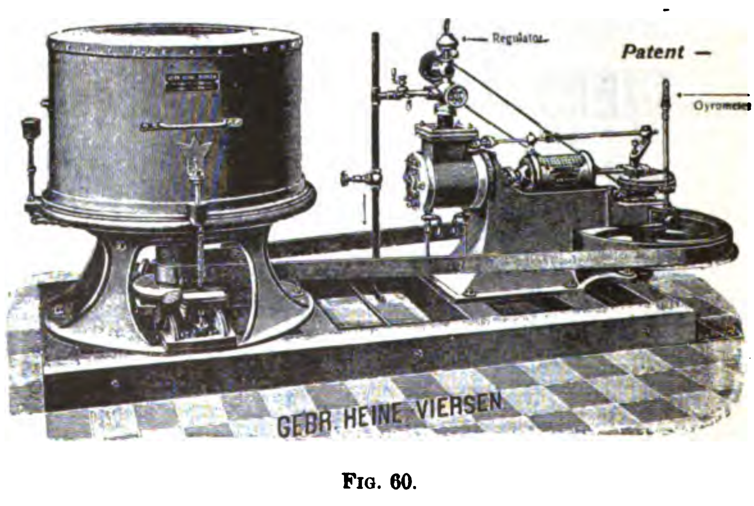


Fig. 60.

chine be balanced when empty, the centre of gravity may leave the geometrical line of the axis when working with materials which do not distribute themselves evenly, and this will produce an unbalanced centrifugal force, causing vibration which increases with increase of speed, and may become so violent as to wreck the whole machine. For this reason the greatest care should be used in the handling of such machinery, as, even when made of the best material, it is liable to explode, and in any case the power required to drive it will be much increased. This driving power

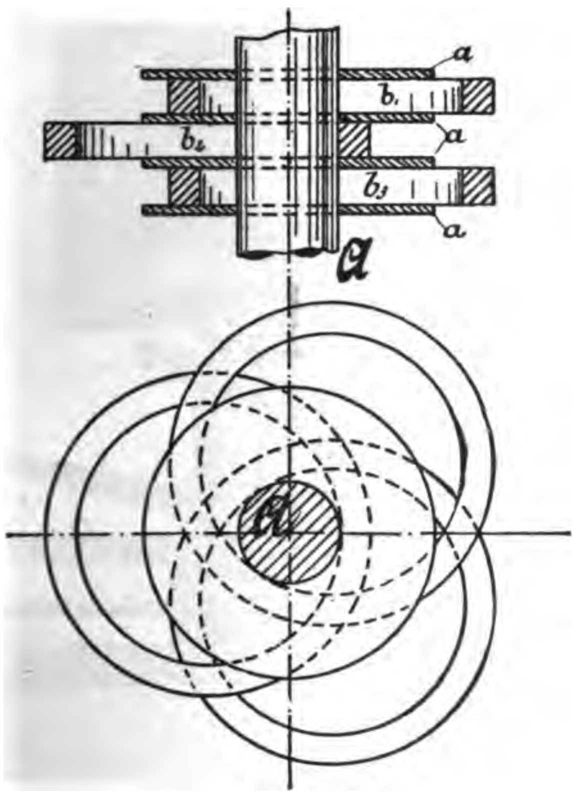


FIG. 61.

when at full speed is not great for a well balanced machine, but is very considerable during the period of starting and during the period when a load is being run in; great care should be taken, therefore, never to overload a machine, and the basket when made of steel plate should have the edges welded throughout their length, never riveted. As a safeguard every machine is provided with a strong steel outer shell, but this is not a guarantee of immunity from danger in case of explosions, as the writer has seen such a shell straightened out like paper and the rivets sheared as with a knife. Too sudden application of the brake, as well as too sudden starting, may be the cause of an explosion.

8. Since an unequal load of as little as a pound of material is sufficient in a swift-running machine to cause vibration, it is important to avoid even slight amounts of unbalancing, and to do

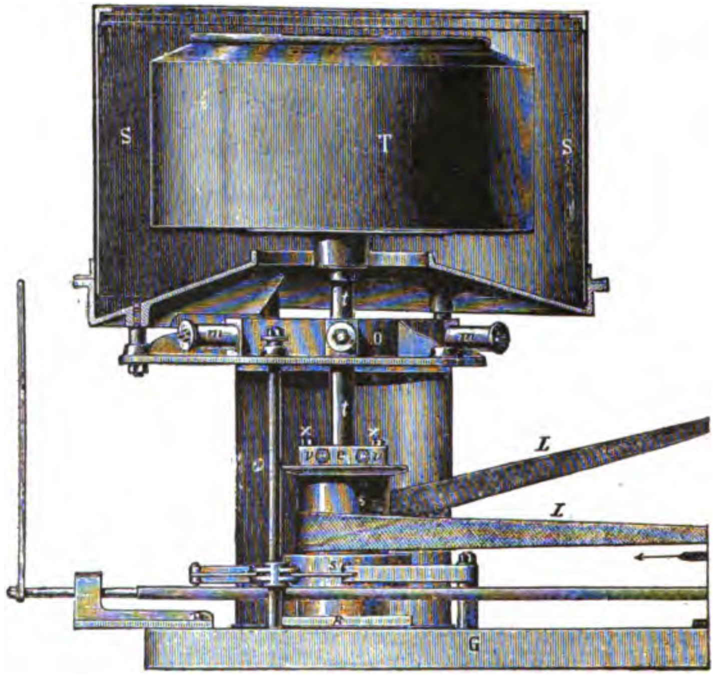
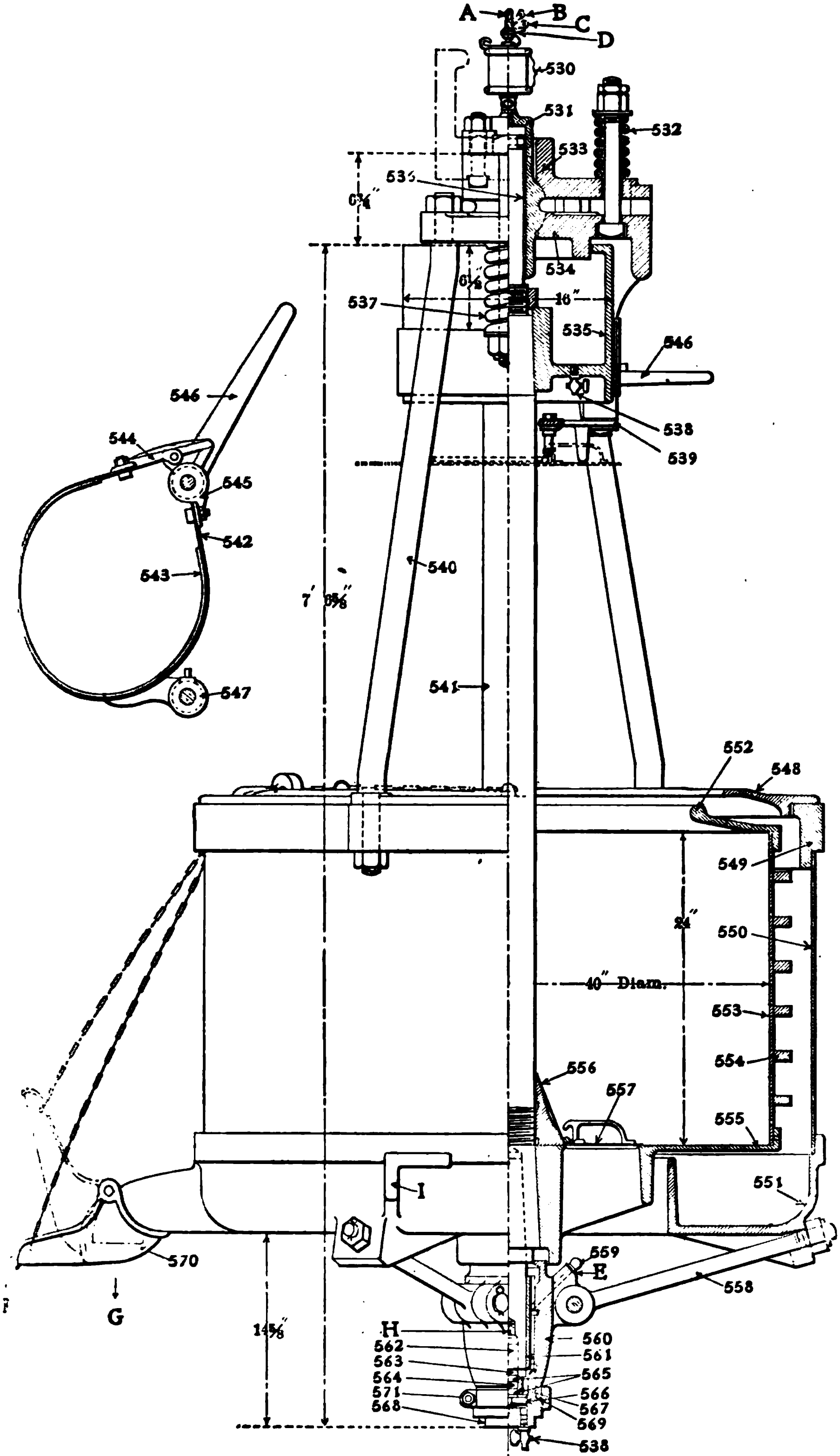


FIG. 62.

this Albert Fesca devised the ingenious regulator, shown in Fig. 61 in detail, and in use on the machine in Fig. 62. The balance rings run between washers *a*, and are free to swing in any position. Because of the friction between washers and rings, the rings will rotate with the shaft, but they will always shift to keep the centre of gravity of the system in the axis of rotation. When the basket is exactly balanced the rings will stand at 120 degrees with each other, as shown in Fig. 61, but if unbalancing occurs, the rings will swing towards the light side, the limit of effect being reached when all three are on the same side of the shaft.

Another device to accomplish the same purpose is shown in Fig.



A
B
C
D
530
531
532
533
536
534
535
537
546
538
539
540
541
542
543
544
545
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
E
F
G
H
I
16"
40" Diam.
24"
7' 8⅝"
14⅝"

Fig. 82

63, which is a Hepworth machine of American manufacture. Here the lower bearing is so braced to the outer casing that the relative position of the two is fixed, but the casing is hung so that it may swing with the rotating part. As a matter of fact, however, practically no motion results, as the inertia of the casing is sufficient to take up any unbalancing. In this way very little strain is brought on the step-bearing, and the objection sometimes made that it consumes considerable power is not well founded.

9. The real disadvantage of this type of machine is that the bearings are inaccessible, but this has been overcome in later forms as shown in Fig. 63. The centre of the ball-shaped enlargement of the upper bearing, 531, is the fixed point about which the entire machine swings; the socket, 533, is bolted to the top of a beam shown in dotted lines, and the bearing extends through the beam and into the socket. The lower part of the socket forms the head, 534, which supports by means of iron rods, 540, the lower part of the machine. The pressure on the ball-and-socket joint is regulated by the springs, 532. By study of the figure it will be seen that all parts of both the upper and lower bearings can be quickly removed by the loosening of a few nuts without taking apart the basket or the main shell. Both bearings are self-aligning, the upper one by virtue of the ball-shaped enlargement and the sockets, and the lower one through being hung by link connections on three rods, 558. The brake, which is shown in detail at one side, is self-releasing, as in most other types of centrifugal machines, and self-adjusting. It consists of a band of steel, 542, with leather lining, and tightened by a bell-crank lever, 546. The discharge valve, 557, is a steel circle, which is lifted and placed on a hanger, 539, when the basket is to be emptied.

10. The difficulty with an under-driven centrifugal machine is to secure a suitable form of step-bearing, especially if the machine is made for heavy loads or high speeds, as in the manufacture of cube or loaf sugar. For this class of work the load runs as high as 4,000 to 6,000 pounds, and with the heavy basket and the heavy motor, since the motive power is usually a water wheel or electric motor, the friction becomes very great. For such purposes the oil pressure step-bearing designed by Fesca is an important improvement. It is shown in detail in Fig. 64, and applied to a macine in Fig. 65, which is the motor-driven type. The construction known as Adant's system is a combination of the

rigid bearing with the buffer, uniting the advantages of both systems. In this step-bearing, the pivot *Z* of the vertical axis, slightly conical, fits the bearing *L* exactly, when the pin *s* rests on the plate *P;* when oil at sufficient pressure is forced through the pipe *y* the pivot *Z* is raised, the pressure needed being given by the equation:

$$\frac{\pi d^2}{4} p = G,$$

where *d* is the diameter of the pivot, *G* the weight of the basket and attachments, and *p* the pressure. The height by which the

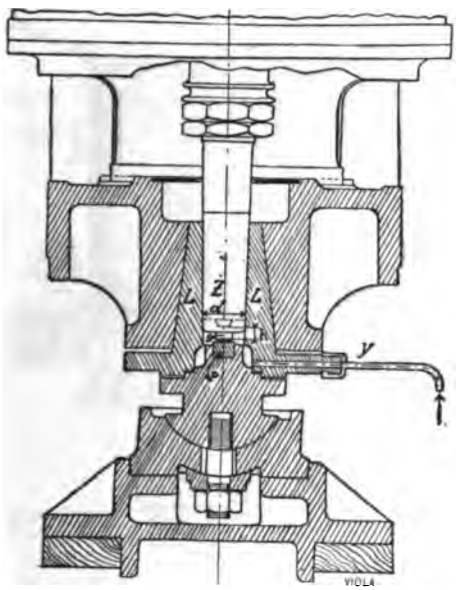


FIG. 64.

pivot is lifted can be determined by the angle of inclination of the conical pivot and the quantity of oil which is fed in continuously by the pipe *y*. Let *h* be the height through which the pivot is to be lifted, and α the angle of inclination of the pivot surface to the axis, then d_1, diameter at the height *h*, will be given by the equation:

$$d_1 = d + 2h \tan \alpha,$$

and the cross-section at this point for the passage of oil will be

$$A = \frac{\pi(d_1^2 - d^2)}{4} = \pi (dh \tan \alpha + h^2 \tan^2 \alpha).$$

11. In this equation the second term of the right-hand member may be neglected, and the expression will then become,

$$A = \pi\, dh \tan \alpha,$$

Through this section the quantity Q must pass in unit time with a velocity,

$$v = \frac{Q}{A} = \frac{Q}{\pi\, dh \tan \alpha}.$$

With the passing of the oil through the narrow annular opening,

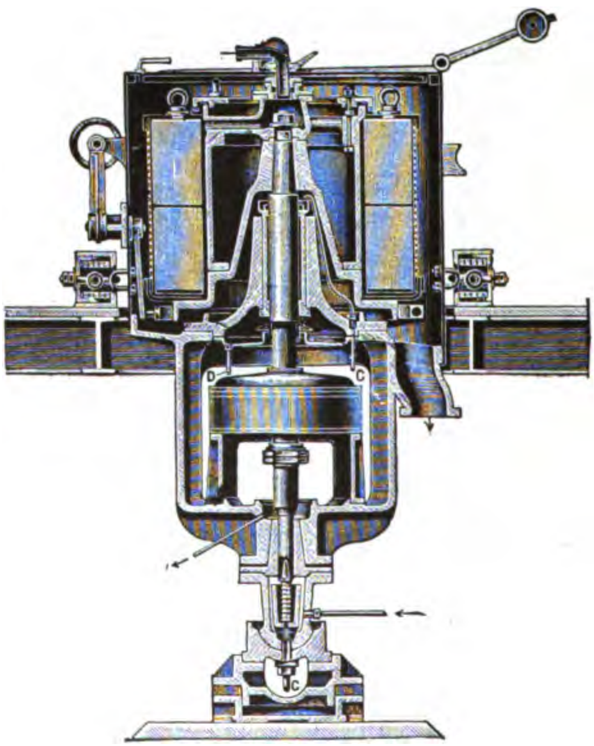


FIG. 65

there will be a certain resistance per square inch proportional to the square of the velocity, which may be expressed:

$$w = Kv^2 = K \frac{Q^2}{\pi^2 d^2 h^2 \tan^2 \alpha},$$

where K is a constant as obtained by experiment. But the resistance w is equal to the pressure p of the basket on the liquid, $p = \frac{4G}{\pi d^2}$, hence we may write,

$$\frac{4G}{\pi d^2} = \frac{KQ^2}{\pi^2 d^2 h^2 \tan^2 \alpha},$$

or,

$$h = \frac{Q}{2\sqrt{\pi} \tan \alpha} \sqrt{\frac{K}{G}},$$

from which it will be perceived that the lifting of the basket is proportional to the quantity of oil flowing, Q, inversely to the tan-

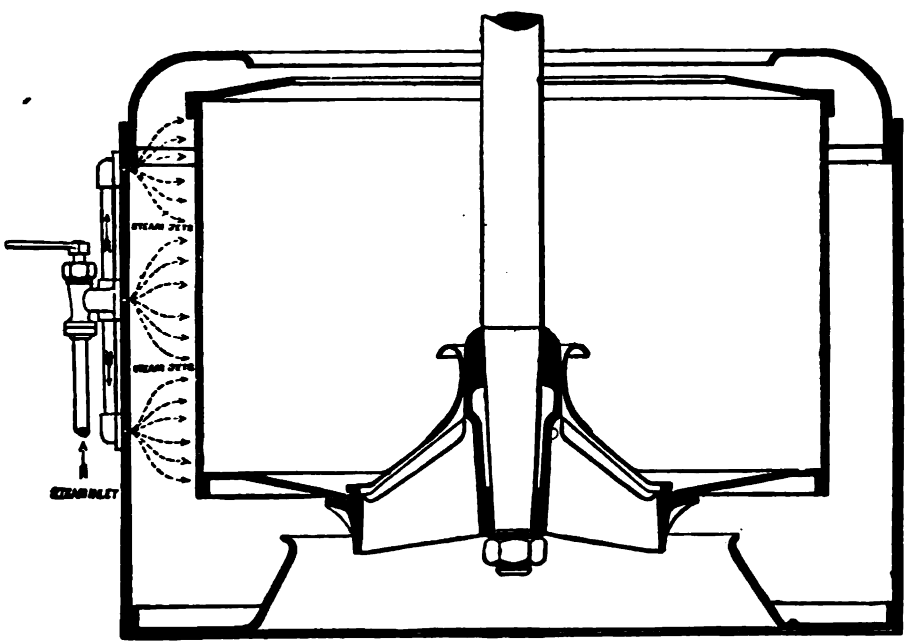


FIG. 66.

gent of inclination and inversely as the square root of the weight of the basket. Hence by changing the angle of the pivot or by regulation of the amount of oil pumped through the bearing, the amount of lift can be regulated between 5 and 10 millimetres above the step. As the pivot is running in a bath of oil the friction will be very slight, and for circulating the oil to keep up this bath a small belt-driven pump is used with a by-pass between suction and discharge through a safety valve.

12. In all the constructions considered every precaution is taken to secure smooth motion, but it may happen that material handled has a tendency to shifting which can only be overcome by the following improvement: This occurs mostly with low sugars and citric and tartaric acids in the lower conditions, when the small crystals contained in liquor will, by the rapid formation of thin scale on the inner surface of the basket, stop the free drainage. This action may take place unequally, resulting in a considerable

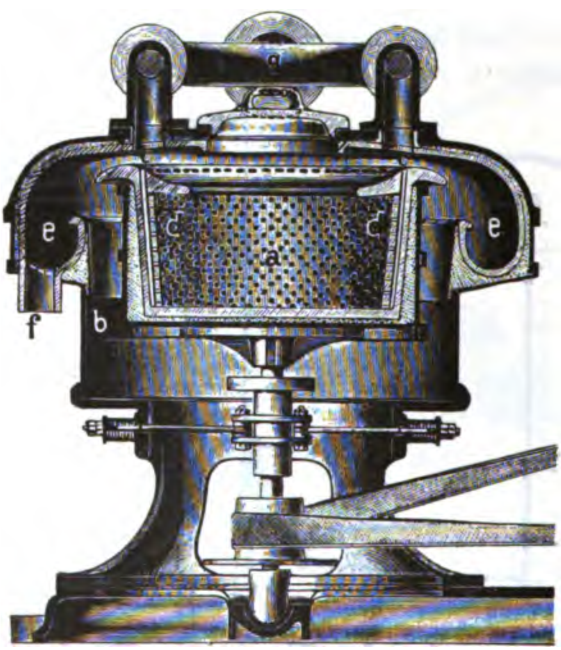


FIG. 67.

vibration, and to open up the outlets a steaming-out pipe, so called, is used, as in Fig. 66. Of course some of the material will be dissolved by the steam jet, but this is of less importance than the complete drying of the material.

13. As already mentioned, the baskets are made according to materials to be separated, of steel, bronze, aluminium, silver, china, etc. Those for use with acids are usually lined with lead, though sometimes hard rubber or enamel has been used. Fig. 67 shows a machine for acids in which the basket, *a*, is made of burned clay, fitting exactly inside the steel basket, *c*, thus pre-

venting bursting. Liquor passes out of the lining through the holes *d* and the vertical canals *c*, so that when the machine is at rest no liquor can escape, but when it is in rotation, the centrifugal force propels the liquor through the holes *d* and canals *c*, and over the rim into the chamber *e*, whence it passes through the opening *f*; the tray *e* is cast in an iron vessel and covered on top with a clay cover, the joint being packed with rubber; the acid fumes are carried off through the pipes *g*. It often happens in

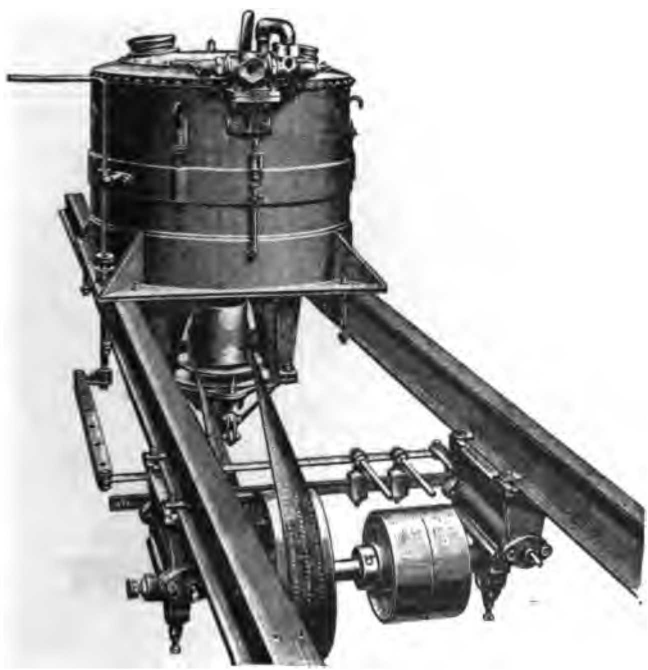


FIG. 68.

chemical works that materials mixed with explosives are to be separated; in such cases the greatest caution must be used, and the machine must be closed air-tight, as seen in Fig. 68. The writer was asked some time ago if it would be possible to centrifugate some ground material which was soaked in benzine. He advised not to do it, but it was, nevertheless, tried, and the entire machine broke out in flames because of the great friction of the gases evolved by the benzine as they came in contact with the air.

14. In the class of machinery known as milk-separators, a

rapid revolution causes separation of the cream and milk on account of their different specific weight. The heavier milky parts flying to the outside of the basket, while the cream will remain on the inner surface of the milk, both these layers may then be taken off by proper suction nozzles, thus giving a continuous operation.

In the separator shown in Fig. 69 milk passes from the vessel T through the pipe V, to the bottom of the drum and inside of the ring P, whence it rises between this ring and the bottom of the

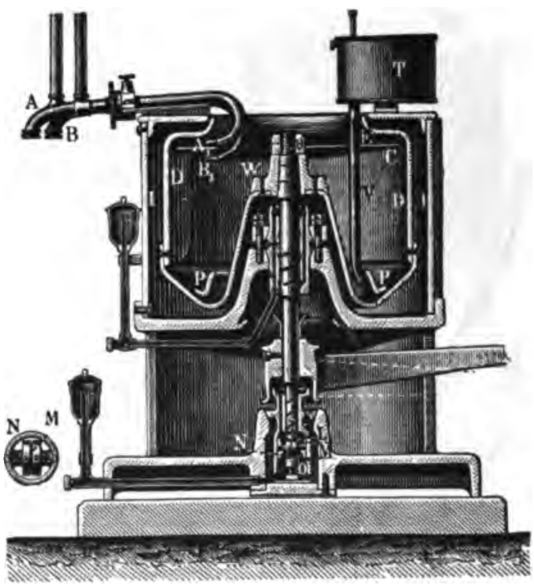


FIG. 69.

drum, and is set in revolution by the wings inside the basket. The cream is drawn off through the pipe B by means of the nozzle B_1, which has a very fine edge and literally peels the cream from the milk, which passes away through the nozzle A_1 and the pipe A. By changing the position of the mouth-pieces A_1 and B_1 any grade of cream desired can be secured.

15. Figs. 70 and 71 show a form of separator of American manufacture, which is of different construction from the one just described. It not only separates cream from the milk, but may be used to purify either one. It is a recognized fact that souring of milk and its products is caused by the presence of

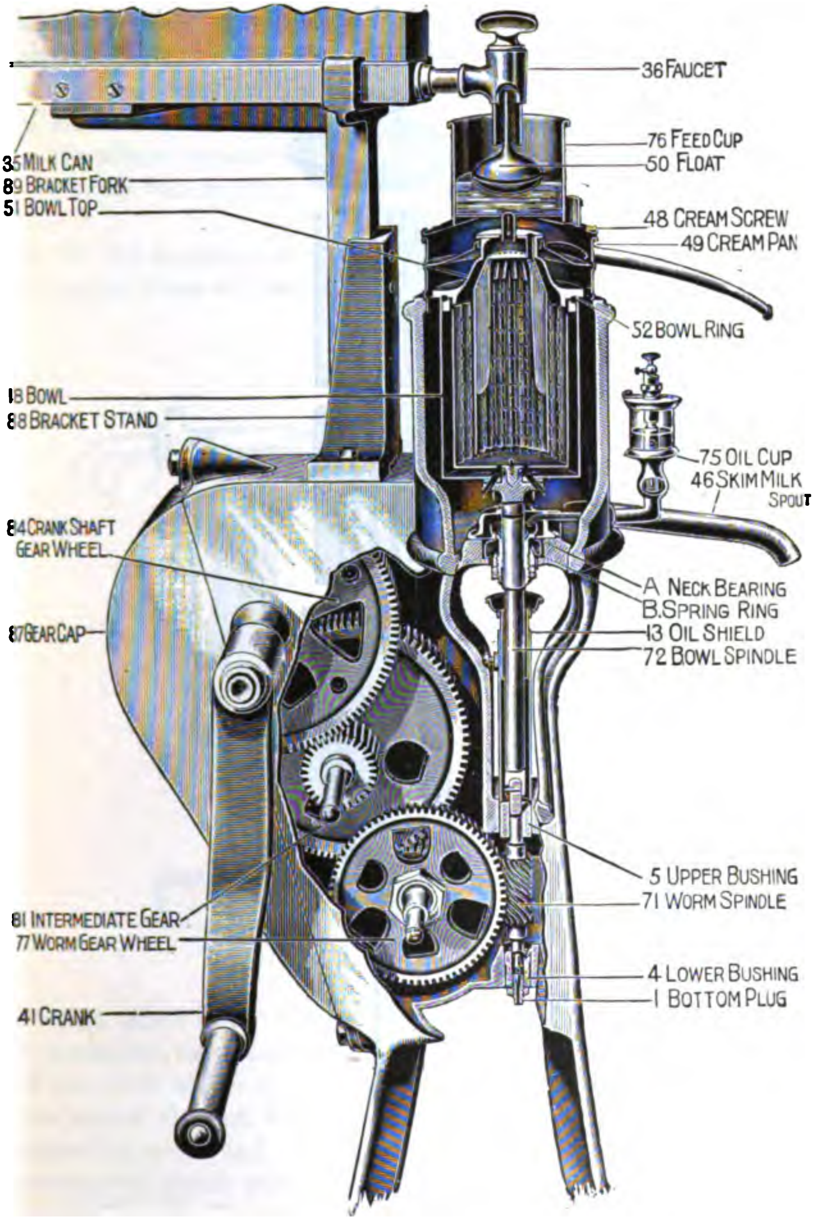


FIG. 70.

bacteria, and the more these can be removed the better will be the keeping qualites of the product. Prof. H. W. Kahn, of

Wesleyan University, a recognized authority on dairy bacteriology, says: "When we examine the amount of solid material

Fig. 71.

which finds itself into the milk we are amazed at the results. This dirt is largely composed of manure, but the microscope has also revealed undigested hay, mould, hair, shavings, woollen threads, earth, cobwebs, particles of skin, human hair, pieces of insects and down from birds." The action of centrifugal force removes from milk this foreign matter, which is such a fertile source of bacteria, and any one who has examined a separator bowl after a separation, can readily believe the above statement. The immediate separation of milk as it comes from the cows before harm has resulted is a very necessary factor in purification.

16. In the operation of this separator milk is fed into the top of the cover, whence tubes conduct it to the inner cup 2, in which

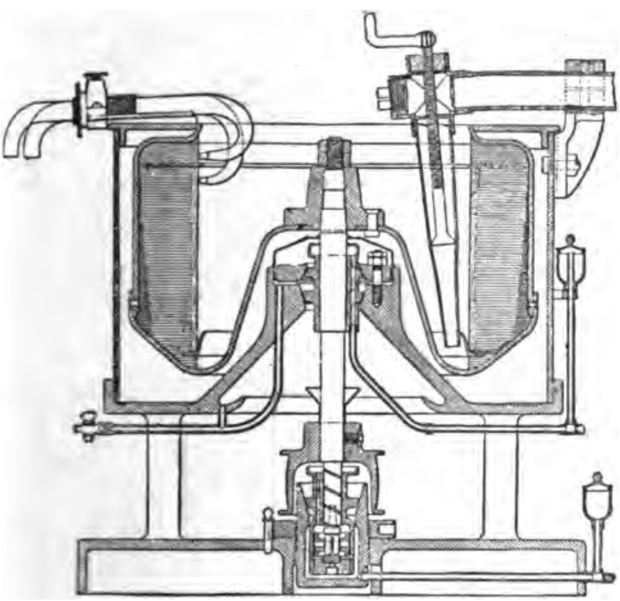


FIG. 72.

are wings which cause the milk to revolve with it; thence the milk passes into the intermediate cup 3, and from there to the main bowl 4, so that, before the milk leaves the machine at the bottom, it has passed through three compartments, each of which is a separator in itself, and to this is due the remarkably thorough separation for which this machine is noted. The internal mechanism is shown in Fig. 71, where it is seen that the spindle is in two parts; the spiral worm, 71, which is the lower piece, is held in position by a bearing at each end, in order to insure exact meshing with the worm wheel, 77, the tip end of this spindle and the lower end of the upper part which is fast to the bowl,

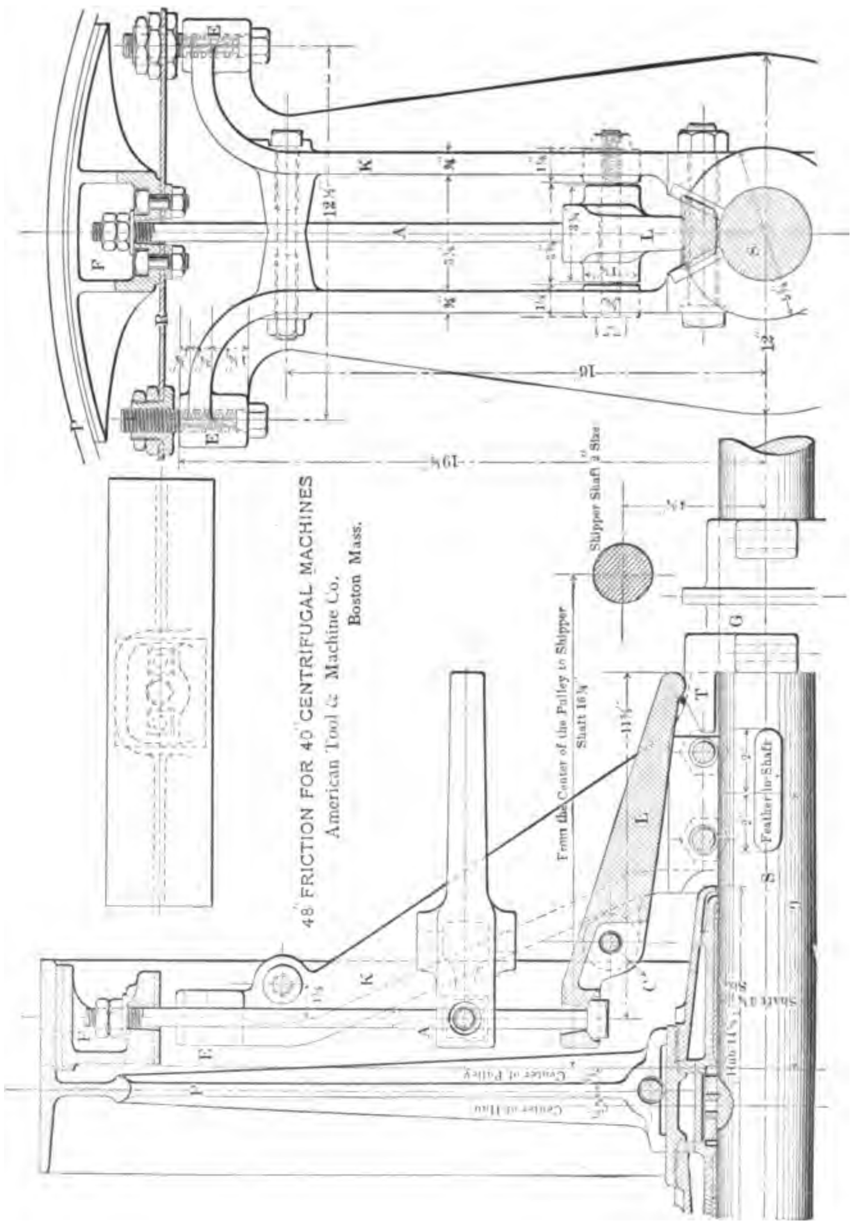

48" FRICTION FOR 40" CENTRIFUGAL MACHINES
American Tool & Machine Co.
Boston Mass.
Shipper Shaft 2" Size
From the Center of the Pulley to Shipper Shaft 16 1/2
Feather in Shaft
Center of Pulley
Center of Hub

FIG. 73.

form a ball and socket joint, so that the bowl may vibrate and still allow the worm wheel to give the proper speed without straining and friction. Also the worm can be replaced at any time without disturbance of the basket.

17. Centrifugal machines are at present somewhat used for

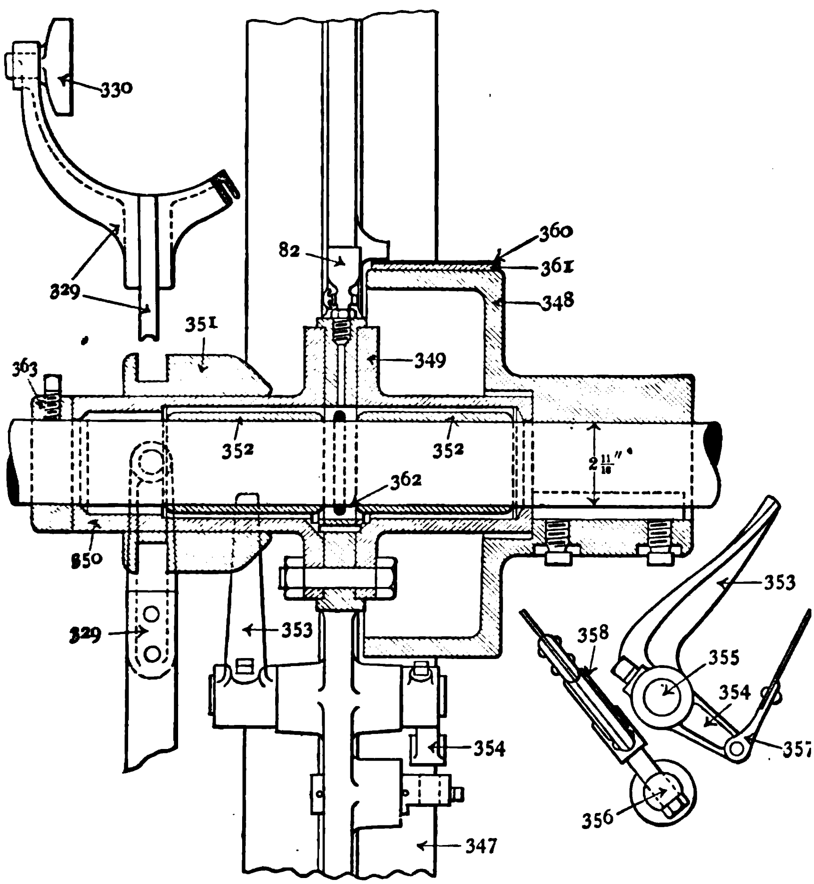


FIG. 74.

filtering one for this purpose being shown in Fig. 72 for use on cane juice. The juice is introduced at the bottom of the drum, and rises, as in the case of Fig. 69;the heavier scums are precipitated on the sides of the revolving drum and, rising above the diaphragm, are collected through the upper nozzle, while the clear juice is drawn off from the inside by the lower nozzle. The filter is not, however, capable of as universal application as the ordinary filter press.

18. Passing now to the driving mechanism, it has been seen that in many machines a tight and loose pulley are provided on the counter shaft from which the machine is driven by belting. A friction pulley will serve the same purpose, and has certain advantages, in that a greater speed ratio can be easily obtained, also the amount of force which can be transmitted can be automatically regulated, so that it will be impossible to transmit more than the desired amount of power. The adaptation of a friction drive to a Weston spindle machine is shown in Fig. 73. Here *P* is the pulley proper moving loosely on the shaft *S*; *K* is an arm keyed to the shaft, and carrying two levers *L* pivoted at *C*. To these levers are attached the friction arms *A*, the latter being in turn connected to the arm *K* at the ends *E* by means of flexible springs *R*. On the end of arms *A* is fastened the shoe *F* faced with leather, and fitting accurately the inside of the rim of pulley *P*. Under the action of centrifugal force the arms *A* will tend to fly outward, engaging the shoe *F* with the pulley, but the engagement may be prevented by means of the sliding sleeve *G*. The springs *R* prevent the sudden action of the clutch, with consequent strain and shock. The usual bronze bushing and oil chambers are provided for the loose bearing of the pulley.

19. A friction pulley of a different form, the Hepworth construction, is shown in Fig. 74. The pulley is loose on the shaft, and engages with the drum 348, keyed to the shaft by means of a leather-lined steel band, 360, encircling the drum. One end of the band is attached to the pulley by mans of a bolt passing through the stud 356, and the other attached to a bell-crank lever, 353 and 354, operated by the sliding cone, 351. By means of the bolt the band is so adjusted that when the cone is pushed towards the pulley the band is tightened on the drum to a point where it will pull a little less than the belt, for it is desirable to have the centrifugal start up quickly, but if the belt slips instead of the band it will leave the pulley. The bronze bushing in the pulley is made to slip both on the shaft and in the pulley; naturally it will turn at the smaller diameter, unless the shaft bearing becomes dry, when the bushing can turn in the pulley rather than to cut the shaft.

30. The following tables are based on the experience of Watson, Laidlaw & Co., Glasgow:

Laidlaw's Patent Self-balancing Centrifugals.

(Weston Type.)

Diameter of Basket.		Power Required for one Machine.	Revolutions of Basket per Minute.	Capacity of Basket.		Safe Working Load.	
Inches.	Mm.	I. H. P.		Cubic Feet.	Cu. Metres.	Pounds.	Kilogr.
24	610	3.00	1500	2.38	0.0673	170	77
30	762	3.75	1200	4.2	0.1189	300	136
36	914	5.00	1000	5.65	0.1596	390	177
42	1067	6.00	850	8.66	0.2452	600	273
48	1219	7.50	750	10.83	0.3066	750	340
54	1371	8.50	650	13.25	0.3751	900	409
60	1523	10.00	600	14.5	0.4105	1000	455

The "capacity" of the basket is the cubic measurement of the wall of massecuite when the basket is full to the lip.

"Safe working load" is the maximum load of massequite or other material which the standard baskets are constructed to carry at full speed.

The "power," as stated above and on the next table, is for usual working con ditions. When the machines are required to attain full speed in less time than usual, the amount of power stated in the table should be increased in proportion.

Weston's Self-balancing Centrifugals.

(Standard Type.)

Diameter of Basket.		Power required for one machine.	Revolutions of basket per minute.	Capacity of Basket.		Safe working load.	
Inches.	Millimetre.	I.H.P.		Cubic feet.	Cub. metre.	Pounds.	Kilogr.
8	203	.....	4,000	0.075	0.0021	5.75	2.5
12	304	0.50	2,800	0.25	0.0070	18.00	8.0
18	457	0.75	1,800	0.75	0.0212	58	24.0
24	610	1.75	1,500	1.80	0.0509	120	54.5
30	762	3.00	1,200	3.10	0.0877	228	103 5
36	914	3.75	1,000	4.20	0.1189	295	134.0
42	1,067	5.00	850	5.30	0.1500	376	171.0
48	1,219	6.00	750	6.60	0.1868	465	207.0
54	1,371	7.50	700	8.02	0.2270	560	254.5
60	1,523	8.50	600	9.50	0.2689	665	302.0
66	1,676	10.00	550	11.09	0.3140	776	353.0
72	1,828	11.00	500	12.57	0.3559	875	400.0

Baskets which may be run at higher speed and carry heavier loads are of course built stronger in proportion.

LAIDLAW'S PATENT "WESTON" TYPE CENTRIFUGALS.

Table of Powers and Capacity when Treating Sugar.

Diam. of Basket.		Number of Machines to be Driven.																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		Indicated Horse-power.																			
Ins.	Mm.																				
30	762	3.7	7.5	10.5	13.7	17.0	20.0	22.5	26.0	28.7	31.5	35.0	37.5	40.0	43.7	46.0	50.0	54.0	58.0	62.0	66.0
36	914	5.0	10.0	14.0	18.0	22.0	26.5	30.5	34.5	37.7	41.0	46.0	49.5	52.5	57.7	62.5	67.5	72.5	77.5		
42	1067	6 0	12.0	17.0	22.0	27.0	32.0	37.0	42.0	46.0	50.0	56.0	60.0	66.0	72.0	78.0	84.0				
48	1219	7.5	15.0	21.0	27.0	33.0	40.0	46.0	52.0	57.0	62.0	70.0	77.0	84.0	92.0						
54	1371	8.5	17.0	25.0	33.0	40.0	46.0	52.0	57.0	62.0	70.0	78.5	87.0								
60	1523	10.0	20.0	28.0	36.0	44.0	53.0	61.0	71.0	81.0	91.0										

Diam. of Basket.		Sugar Cured per Day of Ten Hours, and per Each Machine.									
		In Refinery. Qualities.						On Plantation. Qualities.			
		1st.		2d.		3d.		1st.		2d.	
Ins.	Mm.	Tons.	Kgrs.	Tons.	Kgrs.	Tons.	Kgrs.	Tons.	Kgrs.	Tons.	Kgrs.
30	762	12.50	12.700	10.00	10.160	7.50	7.620	10.00	10.160	7.50	7.620
36	914	13.75	13.970	11.00	11.176	8.25	8.382	11.00	11.176	8.25	8.382
42	1067	15.00	15.240	12.00	12.192	9.00	9.144	12.00	12.192	9.00	9.144
48	1219	16.25	16.510	13.00	13.208	9.75	9.906	13.00	13.208	9.75	9.906
54	1371	17.50	17.780	14.00	14.224	10.50	10.668	14.00	14.224	10.50	10.668
60	1523	20.00	20.320	16.00	16.256	12.00	12.192	16.00	16.256	12.00	12.192

As seen on this table, the machines are of greater capacity than the standard "Weston" of corresponding diameter. The quantities of sugar cured, given above, have been obtained in actual work; but local conditions and experience must always govern the selection of a suitable number of machines in every case.

WESTON'S CENTRIFUGALS (STANDARD TYPE.)

Diam. of Basket.		Number of Machines to be Driven.																				Sugar Cured per Day of Ten Hours, and per Each Machine.									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	In Refinery. Qualities.						On Plantation. Qualities.			
		Indicated Horse-power.																				1st.		2d.		3d.		1st.		2d.	
Ins.	Mm.																					Tons.	Kgrs.	Tons.	Kgrs.	Tons.	Kgrs.	Tons.	Kgrs.	Tons.	Kgrs.
12	304	0.5	1.0	1.4	1.8	2.2																0.55	.558	0.40	.406	.28	.284	0.40	.406	0.28	.284
18	457	0.7	1.5	2.1	2.7	3.4	4.0															1.56	1.584	1.25	1.270	0.83	.843	1.25	1.270	0.83	.843
24	610	1.7	3.5	5.0	6.0	7.5	9.0	10.5	12.0	13.0	14.5	16.0	17.0									5.00	5.080	4.00	4.064	3.00	3.048	4.00	4.064	3.00	3.048
30	762	3.0	6.0	8.5	11.0	13.5	16.0	18.5	21.0	23.0	25.0	28.0	30.0	32.0	35.0	37.0	40.0	42.0	45.0	47.0	50.0	10.00	10.160	8.00	8 128	6.00	6.096	8.00	8.128	6.00	6.096
36	914	3.7	7.5	10.5	13.7	17.0	20.0	22.5	26.0	28.7	31.5	35.0	37.5	40.0	43.7	46.0	50.0					12.50	12.700	10.00	10.160	7.50	7.620	10.00	10.160	7.50	7.620
42	1067	5.0	10.0	14.0	18.0	22.0	26.5	30.5	34.5	37.7	41.0	46.0	49.5	52.5	57.7							13.75	13.970	11.00	11.176	8.25	8.382	11.00	11.176	8.25	8.382
48	1219	6.0	12.0	17.0	22.0	27.0	32.0	37.0	42.0	46.0	50.0	56.0	60.0									15.00	15.240	12.00	12.192	9.00	9.144	12.00	12.192	9.00	9.144
54	1371	7.5	15.0	21.0	27.0	33.0	40.0	46.0	52.0	57.0	62.0											16.25	16.510	13.00	13.208	9.75	9.906	13.00	13.208	9.75	9.906
60	1523	8.5	17.0	25.0	33.0	40.0	46.0	52.0	57.0	62.0												17.50	17.780	14.00	14.224	10.50	10.668	14 00	14.224	10.50	10.668
66	1676	10.0	20.0	28.0	36.0	44.0	53.0	61.0														20.00	20.320	16.00	16.256	12.00	12.192	16.00	16.256	12.00	12.192
72	1828	11.0	22.0	32.0	41.0	50.0	59.0															22.50	22.861	18.00	18.288	13.50	13.716	18.00	18.288	13.50	13.716

The quantities of sugar cured, given above, have been obtained in actual work; local conditions and experience must always govern the selection of a suitable number of machines in every case.

DISCUSSION.

Mr. August Kruesi.—In paragraph 11 is given the calculation of the oil pressure required on the bearing. The constant K evidently relates to each particular machine. I would like to ask Mr. Viola between what limits it varies?

Mr. Viola.—The limits are very small.

Mr. Kruesi.—About what would the average value be?

Mr. Viola.—The highest is about one.

Mr. William Kent.—I hope the author will make that correction in his paper about what the value of K is, as all these formulæ are of no value unless we know something about the value of the constants.

*Mr. Viola.**—You can put the values in yourself from Q and G. To give a better understanding of the formula about which questions were asked, I would suggest the following example: For instance, the pressure p will be for each square centimetre of the pivot Z when its diameter is 60 millimetres, and the basket weights

2,500 Kgr. $p = \frac{4.2500}{3.14 \times 36} = 88.5$ Kgr. If the pivot, whose inclination to the axis is 1 degree, should be lifted through 5 millimetres, then there will be an opening of 5. $tan\ 1 = 5 \times 0.017 = 0.085$ millimetres, for which there is a ring cross-section of $3.14 \times 60 \times 0.085 = 16$ square millimetres, or the pump furnishes continuously such a quantity of oil as would be pressed by a pressure of 88.5 atmospheres through a ring cross-secton of 16 square millimetres.

---

* Author's closure, under the Rules.

No. 964.*

A FORTY-FOUR-FOOT PIT LATHE.

BY JOHN M. BARNAY, CINCINNATI, O.
(Junior Member of the Society.)

1. THE machine here described was designed to meet the demands of a manufacturing establishment of the heaviest type of electrical machinery. The ever-increasing dimensions of this class of machinery make it particularly desirable that the existing heavy machine tools should be capable of extension of capacity with a view to probable future requirements, and that a pit lathe is peculiarly adapted to such extension will, doubtless, be readily admitted.

The face plate of this machine measures 30 feet in diameter, and the present dimensions of the pit will admit of swinging 44 feet on centres, with a maximum width of 12 feet. The large face plate is built up of twelve segments. The rim is of box section, the ends of the rim in each section being finished to make the joint, and the segments being held together at the rim by body-bound bolts. The arms are slotted for bolts, and the space between segments is also shaped to receive the usual square-headed bolts. The inner end of each segment is fastened to the smaller face plate by several body-bound bolts.

2. The smaller face plate is cast in one with the forward section of the spindle. The spindle revolves in a babbitted bearing measuring 48 inches diameter by 68 inches long, the dimensions of the rear bearing being 22 inches diameter by 28 inches long. It is calculated that the pressure on the main bearing will, at times, attain a maximum of 125 pounds per square inch.

3. Teeth were cast into the periphery of the 12-foot face plate for the purpose of driving same while turning up the spindle bearing, which operation is illustrated in Fig. 75. After the spindle was finished by this method the segments of the large face

---

* Presented at the New York meeting (December, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

plate were bolted on, the spindle assembled on the headstock, and the periphery of the 30-foot face plate turned off, with the spindle in its own bearing.

4. A feature of interest in connection with this machine is the method of drive adopted, which is a friction roller, 18 inches diameter, made of compressed paper, while the rim of the large face plate, 15 inches wide, affords the necessary contact surface for driving. Power is supplied by a 75-horse-power motor, quadruple

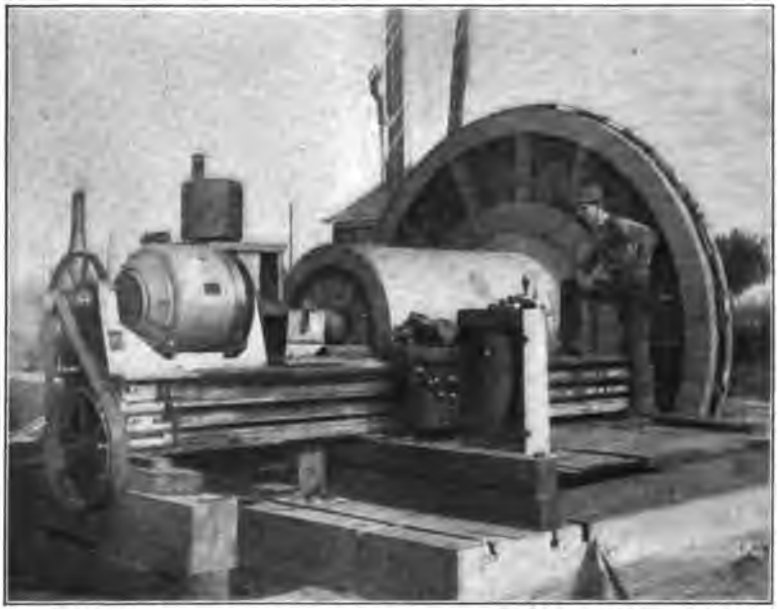


FIG. 75.

geared, the use of the multiple voltage system giving the machine a range covering all diameters from six feet to the present capacity, though the gear train is designed to admit of two changes of back gear in addition.

5. The tool carriages are supported on massive cast-iron columns resting on the bottom of the pit, and the feed mechanism is driven by an independent motor properly back geared, Fig. 77. By the use of the multiple-voltage controller, and a device called a feed regulator, any rate of feed from $\frac{3}{64}$ inch to $2\frac{3}{4}$ inches per minute can be had without a change of back gears. There was also designed for this machine an outboard bearing to support the outer end of man-

drils and boring bars, which is provided with a geared sleeve connected to a train of back gears driven by an independent motor; the whole being self-contained and constituting a portable boring and facing tool.

6. An approximation of the total amount of cast iron used in the construction of this machine places the weight at 480,000 pounds, of which the spindle and two face plates together weigh about 155,000 pounds.

7. As would be expected in this class of tool, the centre of

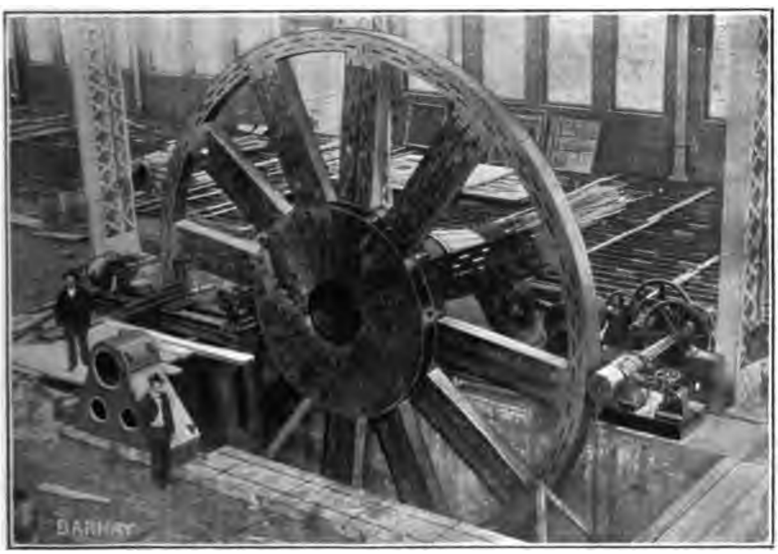


FIG. 76.

gravity of the revolving parts lies very close to the edge of the pit; hence, the matter of a substantial foundation became one of considerable importance, and to meet the severe requirements the design of the headstock provides a large area for the distribution of this pressure, so that the forward part of the headstock alone covers an area of 68 square feet. The masonry foundation consists of a layer of the best Portland cement grouting on top, followed by a five-foot layer of vitrified brick, which in turn rests on a massive column of the best grade of pressed brick, all laid in first quality Portland cement.

8. Fig. 76 shows the assembled pit lathe driven by the friction roller while taking a heavy facing cut, on which occasion four tools

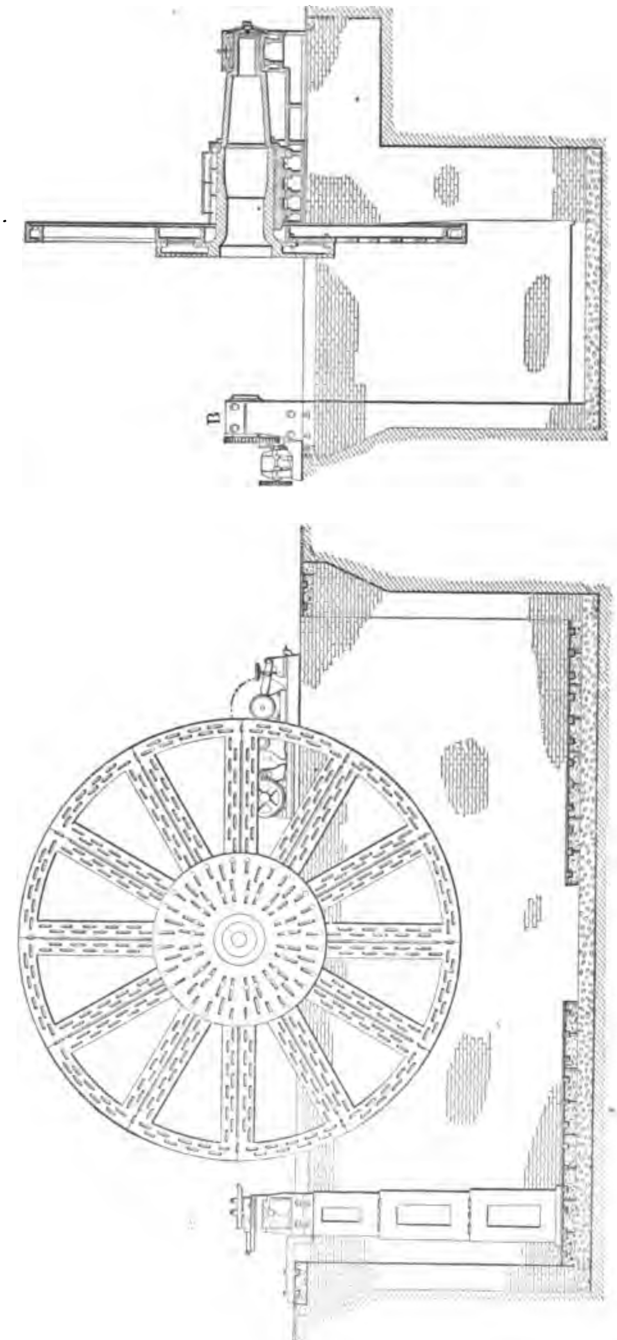


FIG. 77.

were employed. The picture also shows the driving motor with its train of gears and the mechanism employed for adjusting the pressure on the friction roller.

For the illustrations in this paper the writer is indebted to Messrs. Loose and Cooper of the Bullock Electric Co.

DISCUSSION.

Mr. H. H. Suplee.—I have had a good deal of experience in the past with friction driving for another line of work. I think that much more power can be transmitted by it than is ordinarily supposed. Paper frictions somewhat similar to this are generally in use for driving saw-mill machinery, particularly the carriages of band saw-mills, because of the ease with which the mechanism can be reversed. I know, myself, of cases where frictions of 12 inches face are transmitting 35 to 40 horse-power readily without any danger of slip.

M. Fred. J. Miller.—How about the speed?

Mr. Suplee.—I was coming to that. The fundamental point is the speed. Friction wheels, even with very limited faces, can be used to transmit large amounts of power if you only run them fast enough, and the proper way to use those gears is to speed up until you get to the right friction and then speed down again. In that way you can use this very convenient form of drive without any serious difficulty of slipping and without any doubt of transmitting the power.

In the case to which I referred, a paper friction wheel of 12 inches diameter and 12 inches face, running at 600 revolutions per minute, readily drove 35 horse-power, measured by indicating the engine with and without the load, and taking the difference.

Mr. Fred J. Miller.—As I understand it, the ratio between the linear speed of the friction gear and the cut which is being taken, depends upon the diameter of the work. That is to say, if the work is half the diameter of the face-plate then the ratio of the speed of the friction gear to that of the cut will be as 2 to 1. But if the diameter of the work is nearly the diameter of the face-plate, then the ratio will be nearly as 1 to 1, and the question would arise as to whether then it would have sufficient driving power to do much work.

Mr. F. V. Henshaw.—I would like to ask Mr. Barnay how much of the range of speed is obtained by changing the speed of the motor; that is, without making any change in the ratio of the gearing. Also whether in referring to this motor as a 75-horse-power motor he means that it is intended to develop 75 horse-power, driving this tool under any condition of work for which it might be used? I would also like to ask Mr. Barnay for details of this device which he calls a feed regulator.

Mr. Barnay.—I may say that the power behind the lathe is a 75-horse-power motor, and of course the friction, while transmitting that power, is calculated to supply all the power necessary, no matter what the diameter of the work may be.

With reference to Mr. Henshaw's remarks as to the range of speed of the motor, the range of the speed obtained by the use of the controller alone is 1 to $7\frac{3}{10}$. So that in this case any diameter from 6 feet to $7\frac{3}{10}$ times 6 feet (= $43\frac{8}{10}$ feet) can be used in the lathe without changing the back gear at all—simply change the speed by means of the controller.

Mr. Henshaw.—I do not quite follow that. Do I understand that this motor will develop 75 horse-power at any speed over a range of 1 to $7\frac{3}{10}$?

Mr. Barnay.—No, sir. The horse-power is, of course, variable in direct ratio to the speed. As the speed is decreased, the power drops off. The changing gear is useful mainly in maintaining the power of the motor.

Mr. Henshaw.—Does the power necessarily drop off?

Mr. Barnay.—It does, on account of the multiple voltage system. We use lower voltages at the lower speeds.

Mr. Henshaw.—But that does not affect the fact that the lathe may require the same horse-power at any speed.

Mr. Barnay.—As a matter of fact our motors are rated at 75 horse-power; in this case, for instance, at 750 revolutions per minute, and at any other revolution the power would not be the same.

Mr. L. R. Pomeroy.—I would like to ask whether that machine exerts 75 horse-power at the lowest speed?

Mr. Barnay.—Seventy-five horse-power at 750 revolutions.

Mr. Henshaw.—The point I wish to bring out is simply that with a large diameter of work, the material being the same and the amount of metal removed being the same, the horse power will remain the same as for small diameters, because the torque will vary inversely as the speed. I was anxious to get some idea of the actual power of the motor over its speed range for a tool of this size. It appears to me that the rating of the motor as given is misleading, because it can only develop this rated power at one speed.

*Mr. Barnay.**—In reference to Mr. Henshaw's question about the feed regulator, I would say that there is one of these attached to each independent feed screw, and it operates on the principle of an escapement. Its use involves the engagement of an oscillating driving pawl with a toothed disc which is keyed to the feed screw.

Adjustment of the feed regulator causes a variation in the number of teeth taken in by the oscillating driving pawl, thereby changing the rate of speed.

---

* Author's closure, under the Rules.

No. 965.*

GIFT PROPOSITIONS FOR PAYING WORKMEN.†

BY FRANK RICHARDS, NEW YORK CITY.
(Member of the Society.)

1. THE engineer works for results. His agencies are machines and men. It does not appear why it is not as entirely his business to study the efficiencies of the one and the means for their promotion as of the other. The proceedings of this Society have been mostly occupied with the machine, but the man also has been recognized at various times. It is sufficient here to mention the papers entitled "The Premium Plan of Paying for Labor," by Mr. F. A. Halsey, and "A Bonus System of Rewarding Labor," by Mr. H. L. Gantt. The present writing may be taken as a contribution to the discussion which those papers invite and which can scarcely yet be considered closed.

2. They are most fortunate evermore who can work most whole-heartedly. The wage-earners of the world have not hitherto been thus fortunate, and they and the world have been the losers. They certainly have not been so situated hitherto that they could have any desire to do what they could to its utmost, and still less to seek for ways of doing still better. They certainly have a right where possible to more operative and unfailing incentives. How to change the worker's attitude toward his work by means of a change in the system of apportioning the recompense for it would seem to be the foremost problem of the opening years of the new

---

* Presented at the New York meeting (December, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

† For further references on this subject see *Transactions* as follows :

No. 256, vol. viii., p. 630 : "A Problem in Profit Sharing." Wm. Kent.

No. 341, vol. x., p. 600 : "Gain Sharing." Henry R. Towne.

No. 449, vol. xii., p. 755 : "The Premium Plan of Paying for Labor." F. A. Halsey.

No. 647, vol. xvi., p. 856 : "A Piece Rate System." Fred. W. Taylor.

No. 928, vol. xxiii., p. 341 : "A Bonus System of Rewarding Labor." H. L. Gantt.

century. How shall the worker, whatever his grade of skill or efficiency, who has hitherto worked only for a fixed daily wage, be so paid hereafter that he shall not only get all that he earns, but that he shall be willing and even desirous to do more, and thus to earn more, up to the limit of his ability? We have done much boasting, especially as Americans, over the excellence of our machines and over the continuing increases in their efficiencies. Why have we not been equally exultant over the individual efficiencies of our men, and equally diligent and successful in promoting their efficiencies? It is notorious, and it is absurd that it should be so, that the worker finds little satisfaction in his increasing output, and that he takes no pride in it, but rather organizes to retard it as much as he can.

3. The reason seems to be plain enough. Daily wages, and the same wage for each, offer nothing at all to induce one man to do more than another. Why should any man who works for so much a day try to do more than just what will hold his job? Indeed, according to prevalent modes of reasoning, if he does more without commensurate remuneration, what is he but a fool? In spite of all efforts at equalization there is always an appreciable and often a very great difference in the quality or quantity of work done by different men; and if all are paid alike, then either some are not paid enough or some are paid too much, and pay by the day would never seem to be fair and just to all. The system survives, we may believe, chiefly because nothing better and generally applicable has been devised.

4. Other schemes are of course continually being tried, and even adopted, more or less extensively. On the face of it, piece-work, or pay exactly proportioned to the amount of work done, is the only exact justice. Unfortunately, it is sometimes so craftily manipulated that justice deserts it. On the promise of equitable payment for actual work, and in exact proportion to what is done, the worker claims too often to find that in the end it is a mere arrangement to squeeze from him more work for less wages, so that if by day wages some are paid too little, by piece-work a much greater number are ultimately so paid.

5. This estimate of any system which has the name of piece-work is quite widely held by wage-earners. The essential justice of the piece-work system remains, and it might be well worth while to investigate the mistakes, and worse, which have misdirected its application. Instead of that, we have set to work to devise other

schemes. We have now before us, skilfully stated and earnestly advocated, the "Bonus System of Rewarding Labor" and the "Premium Plan of Paying for Labor." The essential error in both of these would seem to be in the ignoring of the strictly business relation of employer and employee. The employer of any worker is simply a buyer of what the worker has to sell, ostensibly paying equitably for what is done and for all that is done. Why, if possible, should he not pay in exact proportion to the quantity done, the same as in buying coal or beef or any other merchantable commodity? If the gift proposition is all right in paying the workmen, why not propose also a BONUS System of Rewarding the Grocer or a PREMIUM Plan of Paying for Beef?

6. Of the two devices here spoken of together, the Premium Plan seems to be the most prominent and to be regarded with the greatest favor. I know that the plan has been devised and proposed in all honesty, and with the most commendable of intentions, and that it has been advocated and promoted by its originator as the fairest thing at present possible between employer and employee, and at the same time an ideal stimulant for the worker; nevertheless, it is for me to speak of it only as I see it.

7. It happens that I am familiar most of all with the things which pertain to machine shops, and with the ways in which things are done in machine shops, including the adjustment, and the various attempts at adjustment, of the pay to suit the work. It happens, also, that the so-called "premium" plan has had its trial and adoption, and what successes it has won, chiefly if not entirely in the machine shop. We will go right into the shop, then, and try to understand the plan and how it works, especially in comparison with the regular old daily wage system.

8. We assume, which it is easy enough now to do, that times are good, that the men have constant work and fair daily wages, and that the employer is finding profit in his business. In the shop are Jack Winslow and Bill Sykes, each running a lathe, the lathes precisely alike, and each turning out the same amount of work every day. Each lathe is worth, as it stands with all its tools and appurtenances, say, $1,000. The proportion of value of the buildings and other details of the general plant chargeable to the individual lathe is, say, as much more. This makes $2,000 as the actual capital that it is necessary for us to consider in this relation. We allow, say, 10 per cent. per year on this value to cover interest, repairs, maintenance, and depreciation; which is $200 per year,

or, say, 65 cents per working day. We will allow for the power to drive the lathe, oil for its lubrication, waste to wipe it, and all that, 35 cents a day. Then there is a share of the office expenses—"non-productive labor," as they call it—and all the other things which it takes to keep the business going; this we may put at 50 cents per day. We will pay each man $3 per day, and then the total daily charge for each lathe will be like this:

Interest, etc., on lathe and plant	$0.65
Power and operating expenses	.35
Office expenses	.50
Man's wages	3.00
Total cost per day	$4.50

9. It makes no difference for our present purpose whether these figures are all just and proper or not. Anyone may assume any other figures to suit his taste. It is necessary to have in addition some figures for the profit to the employer on the day's work, or to fix the value that he may ultimately realize from it. The articles worked on may be parts of machines that are being built in the shop, or they may have to go through subsequent operations that will add to their ultimate cost, but we here assume a value for the work as it leaves the lathe, and which may be realized for that part of the work which is done on the lathe. We will add, say, one-third, or $1.50, for the proprietor's profit, which will make the total value of the day's work of one lathe $6, and of the two lathes $12. We are to remember, then, that, as things are going by regular day work, the proprietor's daily profit for each lathe is $1.50 and that each man's wage for the day is $3.

10. The work of each lathe, with the men thus working by the day, is, say, the boring and turning of ten wheels of a special style for each day's work. Now it so happens that, to keep up with his business, the proprietor needs more wheels than the two lathes are turning out, so he puts in another lathe and employs another man, and when he gets it going it turns out precisely the same amount of work as the others, and the boss and the men are all satisfied. The proprietor's share or profit on the work of the three lathes is $4.50 per day and the sum of the wages of the three men is $9 per day. There is and can be no pretence or suggestion that the third man does not earn his wages as fully as the other two. The idea thus far is the accomplishment of so much work for so much pay, no matter who does it. Each man doing his ten

wheels a day is paid as much for the second five of them as for the first five, and the proprietor gets the same profit out of the last five as out of the first five.

11. With things going along thus satisfactorily, what if a man should take a spurt, and by persistent watchfulness of the speeds and feeds of the lathe, by keeping every cutting tool constantly ready and always at its sharpest, and by celerity and precision in making his changes of work and all the necessary adjustments, he should turn out five more wheels per day? Should he not receive for the third five as much as for the first five or the second five, as long as he had been only equitably paid before?

12. In work that is paid for by day wages there is always this recognized ability in the man to somewhat increase his output if sufficient inducement is offered. There is a "fair day's work" that is recognized as such and accepted as satisfactory all around, and yet which is never assumed to be the extreme limit of a man's possible accomplishment. There are different ways of applying inducements to the men to get them to turn out the possible surplus of work. The proprietor should have no difficulty in recognizing the justice and propriety of paying pro rata for all the work turned out, *as he certainly is paid in that way for all the product of his shop.*

13. Returning now to the two men jogging comfortably along and turning out each his ten wheels a day and getting his $3. The boss to poke them up can simply tell them that he will pay them at the same rate for all they can do. It may then happen that when the men get everything tuned up and have acquired their full momentum they will actually turn out fifteen wheels a day each, and each get his $4.50. Besides the additional wages paid to the men there will be no increased expense to the proprietor, except possibly one or two cents a day for additional power consumed, an item undiscoverable in practice and entirely negligible here. With the three men on the three lathes turning out each his ten wheels a day the men each received $3, or $9 in all, and the proprietor received $1.50 net profit for each man's day's work, or $4.50 in all. Now, with two men doing the same work, although the proprietor has paid in wages to the two men precisely what he paid the three men, he has saved the shop room and the cost of carrying the third lathe. He has saved, in fact, the first three items of expenses as we first enumerated them for one lathe. For the two lathes turning out thirty wheels a day the cost will be:

Interest, etc., on two lathes and plant	$1.80
Power and operating expenses	.70
Office expenses	1.00
Paid two men	9.00
Total cost per day	$12.00

14. The value of the work turned out is, as before, $6 for each ten wheels, or $18 for the thirty wheels, so that the proprietor, although he pays the two men the same amount he paid the three men, actually gets $1.50 more profit, or 33⅓ per cent. more.

15. This might have been done also as a straight piece-work proposition. The proprietor might have said to the men: "Here, you fellows are working all right, of course. I couldn't get any other fellows to do any better work than you are doing, and I haven't a word of fault to find; but, all the same, you know, I'm mighty anxious to get out some more of those wheels. Let's see. You are turning out ten wheels a day; that's thirty cents apiece. Well, I'll give you thirty cents apiece for all the wheels you can turn out; so pitch in, and the more you make the more I'll make, and the better we'll be pleased all 'round." Then, when the men get to turning out their fifteen wheels a day each, the figures will be the same as those last given. Too many bosses get alarmed as soon as the men by piece-work begin to get any appreciable percentage above day wages, and then the cutting of prices begins, and the men soon get disgusted.

16. Now, it's so much better to begin right with the men. The "premium" plan is to be admired for the sweetness of its approach and its avoidance of anything but pleasant suggestions. Imagine the two men working along by the day as before, with the boss as anxious as before to increase his output, but with the "premium" plan in his head. He comes along in his cheerfulest mood and begins to talk it up. He begins to tell how he's got to get out more wheels. "Now, boys," he says, "I know you won't object to raking in a little more cash every Saturday night, and I can put it in your way. I'll tell you what I'll do. I'll go halves with you; and if anything can be fairer than that I'd like to know it. Of course, you are both turning out a fair day's work, but I suppose you could get out a little more if you looked after everything sharp. You shan't run a bit of risk of losing anything. You shall have your full day's pay for the ten wheels you turn out, just the same as now, and for all you turn out over and above the ten you shall have half of what they come to at the same rate.

That's the premium plan that they are working on in a good many shops now, and lots of fellows are getting extra pay by it, and the extra pay is just as good for you as for the rest of 'em, and I'll be just as glad to see you get it."

17. Well, the two men go to work under this "premium" plan, and when they are under full headway, turning out fifteen wheels a day each, the statement for the two men will be like this:

Interest on lathe and plant	$1.30
Power and operating expenses	.70
Office expenses	1.00
Day wages for 20 wheels	6.00
10 wheels at .30 + 2	1.50
Total cost per day	$10.50

For the thirty wheels turned out, as before, the men each receive $3.75, or the two receive $7.50 instead of $9, and the proprietor's profit is increased by the difference, $1.50. The men get $1.50 less and the proprietor gets $1.50 more than by piece-work, every circumstance being identical in the two cases, except that in the latter the men have worked under the "premium" plan. It requires no further demonstration to convince anyone that the plan carries a premium, but take notice who it is that gets the premium; and he who gets the premium should, of course, praise the plan. Those who are getting the premium are the ones to-day praising the plan.

18. I believe I have not here stated the premium plan unfairly, or misrepresented the mode of its presentation by the employer to the workmen. It seems to be proper to ask, as man speaking to man, is this premium plan such as any square-dealing business man would propose to another, or is it what a sharper would propose to a simpleton? Are the exigencies of business such as to necessitate and justify any and every device for wheedling from the workmen as much work for as little wage as possible?

19. One detail of the premium plan which is specially insisted upon by the promoters of it is that it shall be *honestly* administered, and that no advantage—no additional advantage, we might say—shall be taken of the men after it is put into operation, or, in other words, that there shall be no cutting of the rates after they have been once agreed upon. According to the illustration which I have here worked up there would seem to be little need of cutting the rates. Should the opportunity appear and the temptation

arise, however, to cut the rates, there is nothing to prevent it with the premium plan any more than with pure piece-work, and either system is dependent upon the *good faith* of the employer. When the premium plan is put into practical operation the proposition to the men seldom is to give them more than one-half the price, as I have above assumed, for the excess of work produced. The author of the premium plan has said that he favors the giving to the men of one-third, and that he considers an offer of one-half to be dangerous, the danger consisting in the increasing temptation to the employer to cut the rate.

20. If, in the above, I have in any way misrepresented the premium plan, as I certainly have intended not to, I will be glad to be corrected. I do not see that the "Bonus System" differs from the "Premium Plan" except in the details of the device by which the same result is attempted to be secured, and it is not necessary here to consider it.

21. It is my view that for everything a workman can do there is a fair and equitable price, whatever the difficulty of determining that price, and that when the man does the work he should get the price. The piece which by extra exertion he does last brings as much (or, as I have shown, more) profit to the proprietor as the first piece that is done, and it does not appear why the man should not have his pay the same for each. No one can assert that the premium plan gives him this. It does not appear to me that the premium plan, or any other *gift* proposition, offers or suggests a permanent or satisfactory solution of the problem of equitably adjusting the wage to the work, so that the opening century still has a job before it to devise some scheme more equitable and more deserving of permanent adoption.

DISCUSSION.

Mr. Frank Richards.—I have a record of just 40 years of working days in the American machine shop as successively errand boy, apprentice, journeyman, foreman and superintendent, and I am still in pretty close touch with the shop and the men who are in it. Perhaps no one is in a better position than myself for presenting the view which the workman, the party of the second part, is likely to take, the view which, as I believe, he is warranted in taking, of these gift propositions, and his view must sooner or later be reckoned with.

There is in this paper not the slightest suggestion of sympathy or affiliation with the trades union as it is familiarly known. I believe that the idea prevalent in the ranks of organized labor that there is only so much work in the world anyway, and that the less each one does the more there will be left for the others to do, is one of the silliest that ever dominated human action. The winning way of working is, the American way has been, to do all you can—and get paid for the whole of it. The schemes which in this paper I object to are those that aim to get the workman to do all that he can and then to jolly him out of a part of the price. The point of this paper is in the question in the latter part of it. Is the premium plan, or the bonus system or any scheme which offers the man as a gratuity a part only of what he actually earns, is such an arrangement what any square-dealing business man would propose to another, or is it what a sharper would try to work on a simpleton? It may be proper to suggest that in the discussion of this matter no narratives of successful experiments with these gift propositions, no exhibits of cost reductions accomplished, nor even the fact that some workmen are willing to accept some of these self-styled gratuities, have anything to do with the ethics of the case. Is the thing right? If it is right, then it is all right.

After all I am ready to say that this is a matter of comparatively slight importance. I could wish that our attention might be turned to the larger and more urgent problem of general wage adjustment. How can the wage earner or the salaried man be put in a position to rejoice in, rather than to regard with regret and disappointment a time of industrial activity and so-called national prosperity? It is not difficult to understand just what I mean. The most valued men in the shop are the old hands, or they wouldn't be the old hands. All successful and long established businesses have employes who have been with them for years, and the newer establishments try to accumulate men of the same class. Not only is the skill and the rate of production of these men more to be relied on, but it is expected that they will be more patient in the matter of wages. Generally they are not cut down when occasional slack times occur, and in consideration of this it is expected that gratitude will discount their ideas in times of prosperity, and that they will not be alertly clamorous for a raise. Now, the most tangible evidence a workman generally has of national prosperity is an advance in the price of everything that his wages go for. Money as a representation of value is considerable of a failure, as far as he is concerned. The one thing that is forced upon his attention is that its purchasing power goes down, or his wages actually decrease automatically by the same operation which increases the profits of the manufacturer and the merchant. How can he then rejoice in the prosperity which acts as a minus quantity upon his interests? I know well enough that no one is to blame for this thing. The wisdom of the world simply is as yet insufficient for many industrial problems. It is well, however, constantly to remember that while schemes for wage reduction, or for getting

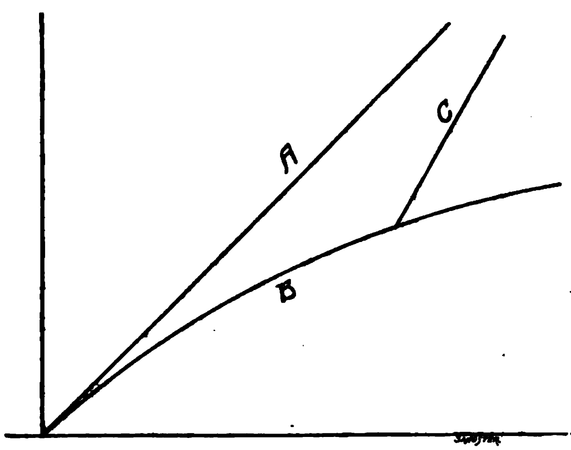


FIG. 78.

as much work for as little wage as possible, may have a place in our system, it is still very necessary that we should have also some device for securing all around increase of wages sometimes when such is only simple justice.

Mr. William Sangster.—Mr. Richards must have advanced his theory for the purpose of starting a discussion. It is directly opposed to one of the most elementary principles of shop practice—*i.e.*, "Reduce Your Labor Cost," and also to every custom of the commercial and manufacturing world. If we represent ability, production or quantity of material involved in a sale, by the curve *A*, Fig. 78, we shall have the usual rate of remuneration or profit expressed by *B*. Exceptional cases may run upward as at *C*, but these are abnormal.

A man receiving $3.00 per day is usually over 50 per cent.

better than a man at $2.00, and, as shown in the diagram, receives less in proportion to his ability.

The wage problem can never be definitely settled. New conditions of manufacture and living continually arise and call for new adjustments. The premium system, all things considered, is the fairest method of settling the problem. A concern has the satisfaction of knowing that, while the men are increasing their own rate of wages, they at the same time are placed in a better position to meet competition. One of the natural tendencies for any concern is to reduce the selling price as soon as the cost of production warrants it. This means a larger business, more men, and, if carried out to its logical conclusion, a benefit to the first wage-earner who finds his cost of living decreased while his wages have been increased.

A foreman who would set a piece-work price at over 70 or 75 per cent. of the day cost would be considered unfit for his position, and even then, if he so wishes, a man can usually turn out such an increase that his wages outrun the proportion of pay to ability. There is no gift proposition about the premium system. It simply ensures that instead of one man doing the thinking for several others, each man is paid for the use of his brains, and his wages are increased according to the usual proportion of remuneration and ability.

Mr. W. D. Ennis.—Mr. Richards makes certain statements in which I, for one, cannot acquiesce. In (12) he advances the idea that there are *two* degrees of industry, each of which is entitled to be considered "a fair day's work." One, he says, "that is recognized as such and accepted as satisfactory all around," and the other that which represents the "extreme limit" of a man's possible accomplishment. My experience and judgment lead me to believe that there is for each individual one "fair day's work," representing not the extreme limit, but the reasonable maximum of accomplishment both as to quantity and quality of product. To get this maximum out of his men is the business of every boss. Piece-work, premium and bonus systems are methods of helping him to obtain it.

My experience with piece-work began when an apprentice at the Rogers Locomotive Works. The system was introduced gradually. No pledges were made with regard to cuts. Several cuts were made, which—so far as my observation extended—were perfectly just. To illustrate, one man, not a machinist, but a day laborer, had the job of drilling stay bolts. Under the day-work system he was apparently a pretty steady worker. He earned $1.25 a day. Put on piece-work his wages increased to $3.00 and $3.25. He was cut severely, but could still make $2.25 per day. As a matter of fact, he worked no harder than by the day, but he kept his wits more about him. Two dollars and twenty-five cents a day was a good high price for that man. He had simply been rubbing it into the Company—doing about 60 cents' worth of work a day for $1.25. Through the piece-work system he was detected. Unfortunately there was no way of getting back the money lost by his former dawdling. That was just so much to the bad. A great many men who had enjoyed snaps under the day-work system were shrewd enough not to give themselves away as he did. They would lay back in the harness just as they had before. Day-workers in the shop got from $2.00 to $2.30 a day—piece-workers were expected to make $2.75 to $3.00 (excepting gang foremen, who sometimes ran up to $5.00). If a man by Friday had done enough work to bring in a pay envelope of about $16.00 to $18.00 he would lay off Saturday. After a while when the checking system was perfected, the office found it out, and there were more cuts. In this case, just as in that of the man drilling staybolts, the cuts were fully justified. The men had been swindling the bosses for years. Of course the bosses were to blame, but even in the very best supervised shops there will be grafts of this kind practiced. A man is paid for a full, fair day's work. In the illustration cited by Mr. Richards, where the employes, by reason of special inducement, increased their output from 10 to 15 wheels per day, I think the average foreman would conclude that 10 wheels were not and never had been, a full fair day's work. He would feel more like letting those men out for playing it on him so long than paying them anything for the 5 extra wheels. The men were not "equitably paid" when they turned out 10 wheels; they were overpaid. The "fair and equitable price," which it is the aim of the piece-work and bonus systems to establish, should not be based on the price under conditions of inefficient, haphazard day-work, but upon the market value of the labor necessary to do the work. This is not measured at all by the value of the increased output; it is determined, like the market value of every other labor or commodity, by the price at which it can be duplicated. To illustrate: A day-worker is put on piece-work and swells his earnings to $5.00 per day. Now everybody knows that average machinists do not earn $5.00 per day. If this man does more or better work than any other man can, he will, of course, get his $5.00; but if another machinist can be hired for $3.00 who can do the same amount of work in a day, the $5.00 man cannot expect to stay.

Furthermore, the daily output under the piece-work system is not entirely due to the skill and speed of the expert machinist. Some recognition must be given the plan of operation—the facilities for economical work, the specialized tools and equipment—provided by the employer. The opportunity of working at one job steadily makes a man especially speedy, without perceptible increase of effort. Shall he be paid excessively for an advantage which is provided, not by himself, but by his empoyler? Is it just to men of other skilled trades to have machinists drop into a gold mine where they can pick up $4.00 or $5.00 a day? Sometimes an unskilled laborer is put on a machine without having served his time. He gets accustomed to his job and easily earns $3.00 to $4.00 a day. The machinists themselves object to this. Yet if, as Mr. Richards puts it, we are to pay according to the value of the product, we ought to pay this laborer just as much as we would a machinist. The truth is, it is not the volume of the product, but the value of the tool, that we pay for when we buy labor. The one is measured by the other, but it is not the same as the other. It is true that the product of the shop is paid for according to its volume; but in this case there is for sale something which represents far more than any one man's muscular exertion. We are then selling, not only labor, but raw materials, transportation, superintendence, reputation and brains. The value of the unit of product-volume regulates itself. It is determined just as the value of labor is determined by the cost to duplicate it.

It has not been my experience that "daily wages and the same wage for each offer nothing at all to induce one man to do more than another." In the most conservative of day-work shops there are inducements for one man to do more than another—the inducement, for instance, of a more congenial job, or that of an increase in pay, or that of promotion to a more responsible place. It is true that there is not enough inducement toward excellence. Piece-work and premium systems are trying to make more, although neither system can long countenance flagrant abuses and extravagances without making cuts. But piece-work will not be a thorough remedy for indolence. The best remedy is the one that lies at hand in every department of life—to make men realize that in a free country, industrial castes are not fixed; that there is room for every man to rise. The best men will rise. It is right that the lower ranks in the trades should be comparatively unattractive. Otherwise, there would, indeed, be "nothing at all" to induce a man to get out of them. Promote the man from the ranks.

The offer of the premium system is not that of a sharper to a simpleton. It is the offer of a man who has a correct judgment of the value of labor and goods to one whose maximum reasonable energies he proposes to pay for. Piece-work is impracticable without cuts. The best type of progressive workman is not the man who has been loafing all his life and who is silly enough to let the fact be known for the sake of making big wages during a single week or two, but the man who aims all the time, whether on piece-work or day-work, to produce work of quality and quantity which will command for him, in one place or another, the best wages paid to men of his trade. That kind of a man gets recognition every time.

Mr. E. S. Boyer.—It seems to me that Mr. Richards has assumed that when each man turns out 10 wheels per day, the men are turning out a quantity which might be expected from the *average* workman. The truth of the matter is, however, that the *average* output is probably never known until the premium plan has been put into effect. Mr. Richards admits that it is the tendency of the workman to do only the amount of work necessary to hold the job, and as the labor organizations require the same pay for each man doing the same kind of work, the tendency of the men is to work to the standard of the least efficient workman rather than to that of the average workman.

Let us assume that there are three men, A, B and C, each running a lathe, the lathes precisely alike, and each turning out the same amount of work per day. We will assume that this work is the boring and turning of 10 wheels of a special style. The wages of each man is $3.00 per day. The total number of wheels turned out is 30, and the total labor cost is $9.00. The labor cost of each wheel, therefore, is 30 cents, and the average output per man per day is 10 wheels.

Now at the end of the first day that the premium plan has been in effect, we would probably find that A has turned out 14 wheels, B 12 wheels, and C 10 wheels. If we give a premium of half the labor cost on the increased output, A's premium would be 60 cents, B's 30 cents, and C, of course, earns no premium. We have obtained a total output of 36 wheels per day at a cost of $9.90, or an average cost per wheel of 27½ cents. We have also learned that the *average* output per man per day is 12 wheels. In other words when we required an output of only 10 wheels per day we were working to the standard of the least efficient man. The effect of the premium plan has shown us that the average output per man is 12 wheels per day, and if we agree with the labor organizations that $3.00 per day is a fair price for the *average* workman on this amount of work, why have we not the right to require the *average* output?

Now if A, B and C each finish 12 wheels per day, the total output would be 36 wheels and should cost the employer $9.00 or 25 cents per wheel. Comparing this figure with the average labor cost of each wheel when the employer requires an output of 10 wheels per day and pays a premium of half the labor-cost on each additional wheel, you will note that under this premium plan the employer is paying 2½ cents per wheel more than he justly should.

Mr. H. M. Norris.—I have somewhere heard a jingle which runs, as nearly as I recall, as follows:

> Some say the world is bad
> As others try to make it,
> But whether it is good or bad
> Depends on how you take it.

which, I think, applies to one's opinion of the relative merit of the two systems under discussion. Almost any system can be made to appear better than another when conclusions are drawn from comparisons based on assumptions, but conclusions thus reached are apt to be far astray from the actual results derived from a practical application of the system.

Mr. Richards appears to lay great stress on the "justice and propriety" of paying *pro rata* for all work, but I fail to see why he concerns himself with questions of this sort. If it takes 5 hours to machine 5 pieces of work, what possible difference does it make to the workman whether he is paid 40 cents for the first piece, 35 cents for the second, 30 for the third, 25 for the fourth, and 20 for the fifth, or at a *pro rata* rate of 30 cents each? The result is identical, as is that derived from the piece-work and premium systems—*provided one knows how to fix suitable rates.*

It is customary, I believe, to fix piece-work prices 20 per cent. lower than the work cost when made by the day, while under the premium plan the time limits are usually fixed according to the time spent on the work under the day's-work plan. Comparing the earnings of Mr. Richards' two men on this basis, we find that the result is quite different from that shown by him—that instead of the workman's earnings being greater under the piece-work system, they are 4 per cent. greater under the premium plan, as per figures below, in which the premium is figured at one-half of wages:

	Premium Plan.	Piece Work.
Interest on lathe and plant........	.65	.65
Power and operating expenses.....	.35	.35
Office expenses..................	.50	.50
Wages at time limit of 1 hour each	3.75	.....
Wages at 24 cents per wheel	.....	3.60
Total cost per day............	$5.25	$5.10

From which it would appear that, properly administered, *either system is equally fair to men of equal skill.* We know, however, that there is not in one of our works two men who are able to produce an equal amount of good work within any given period of time, and it is due mainly to this fact that the premium plan has, in the opinion of so many, proven superior to the older system.

For example, suppose the rate-fixing department estimates that 10 hours is a fair allowance for cutting a lot of 16 gears, and that it is willing to pay a premium of 9 cents per hour if the work is gotten out in this time. The time limit would then be fixed at $10 + [(10 \times .09) \div .15] = 16$ hours, while if the work were to be given out under the piece-work system the department woud probably figure as follows: $[10 (.30 + .09)] \div 16 = 24\frac{3}{8}$ cents each, in which event the average premium-worker would be expected to earn $[.15 (16 - 10) + (.30 \times 10)] \div 10 =$ \$ .39 per hour, while the average piece-worker would earn $(16 \times .24\frac{3}{8}) \div 10 =$ \$ .39 per hour also.

So far so good, but the next lot is assigned to workmen who consume 12 hours in performing the work. The premium-worker then earns $[.15\,(16 - 12) + (.30 \times 12)] \div 12 =$ \$ .35 per hour, while the piece-worker's earnings are but $(.24\frac{3}{8} \times 16) \div 12 =$ \$ .32½ per hour.

Now let us suppose that the next time the job is assigned it falls into the hands of the two best men in the shop, who get the work out in 8 hours. The premium-worker would then earn $[.15\,(16 - 8) + (.30 \times 8)] \div 8 =$ \$ .45 per hour, and the piece-worker $(.24\frac{3}{8} \times 16) \div 8 =$ \$ .48¾ per hour. Putting these several results in the form of a table, we see that

System under which Work is Performed.	KIND OF WORKMAN.		
	Poor.	Fair.	Best.
Piece work	.32½	.39	.48¾
Premium plan	.35	.39	.45

if the rates are right for the "Fair" workman, the "Best" men earn most under the piece-work system, while the "Poor" ones earn most under the premium plan. Under the latter the "Best" men earn 10 cents per hour more than the "Poor" ones, while under the former the "Best" men earn 16¼ cents per hour more than the "Poor" ones, which, to my mind, is a grave fault, in that it offers too little encouragement to the poor men, and overpays the best. By "overpays" I mean that it rewards the men more than necessary. The object of both systems is to reduce cost to the lowest possible figure, and the question is how much must be paid to effect this reduction. If too little is offered, the object will fail, while if too much is offered the surplus is a direct loss.

Rate-fixing, at best, is always more or less a matter of educated guessing, and other things being equal, that system is best which best protects both parties to the agreement. Suppose that instead of the best men taking 8 hours for machining the above lot of gears they got them out in 5 hours, the premium-worker would receive $[.15\,(16 - 5) + (.30 \times 5)] \div 5 =$ \$ .63 per hour, while the piece-worker would receive $(.24\frac{3}{8} \times 16) \div 5 =$ \$ .78 per hour.

The first increases his earnings 2.1 times, while the second increases his 2.6 times, which, in my judgment, is the opposite from "fair and equitable." Errors in rate-fixing are bound to occur under either system, and if the workman has an advantage when a rate is fixed too low, it is no more than fair that the manufacturer should have an advantage when the rate is fixed too high. It is presumed, of course, that neither will seek an advantage over the other.

Mr. Richards admits that "the premium plan is to be admired for the sweetness of its approach and its avoidance of anything but pleasant suggestions," which is certainly one point in its favor. He must also admit that, since there is less fluctuation in the men's earnings, less care is required in fixing the rates, which will be two points gained. And he can probably be brought to admit that a rate-fixer, realizing that each time a piece price is fixed too high the firm will have to pay exorbitant wages as long as the work is manufactured, will endeavor to err the other way and fix the rates too low, thereby curtailing everyone's average earnings, in which event he must concede a third point, and it is my firm belief that the further he carries these comparisons the sooner he will join the ranks of the advocates of the premium system.

Mr. H. L. Gantt.—To take up even the most pointed issues Mr. Richards offers would require too much time, but the statement in paragraph 2 that workmen take no interest in their work and have no desire to do better, is the reverse of the experience of the writer with men working under *permanent* piece rates, or the Bonus System. If Mr. Richards had read Mr. Taylor's paper on a "Piece Rate System," or my paper on "A Bonus System," and attempted to verify the statements made in them, he would, I think, have left a large part of his paper unwritten. The second is an outgrowth of the first, and is simply an attempt to carry out the same principles in a more elastic manner.

As the Bonus System has been stigmatized as a gift proposition, I shall confine my remarks to a description of the principles on which it is based, and leave to the members the question of assigning it to its proper category.

Our object is to buy labor, and before attempting to do so, we should try to find out as nearly as possible on what conditions those who have it for sale will put it at our disposal. A study of the subject from statistics reveals, among others, the following facts about the ordinary workman :

1. For a fixed daily wage he will seldom do more than a fraction of the work he can do.

2. He usually follows very closely the methods which he has been taught, and is generally incapable of improving them to any great extent without assistance.

3. He is generally satisfied to jog along according to his old methods at his habitual speed for a specific day's pay, but will generally, if a sufficient financial inducement be offered, work to his full capacity and follow exactly instructions laid down.

4. This additional incentive has been found by experience to vary with the class of work from 20 per cent. to 80 per cent. of his day's pay.

If the work is light and the workman is not physically tired at the end of the day, this extra compensation may be as low as 20 per cent. As an actual example of this class, I may cite the running of a metal saw, in which the extra labor of the workman is making changes quickly and seeing that his machine is in condition to do its best work. If the work is such that the man becomes physically tired at the end of the day, this extra incentive must be from 30 per cent. to 50 per cent. The running of ordinary machine tools such as lathes, planers, slotters and drill-presses, come under this head, as do most kinds of ordinary laboring work, such as shovelling coal, sand, ore, etc., the handling of iron, the chipping of castings, etc.

If, in addition to becoming physically tired, the workman has to be subject to unpleasant conditions, such as excessive heat, smoke or gases, he requires a higher incentive to make him do all he can. From 60 per cent. to 80 per cent. will cover the usual conditions of blacksmithing, hammering, and work around furnaces. As an example of an extreme case, I may cite the hammering of tool steel, which falls within these limits.

There are undoubtedly conditions that call for a higher extra compensation, but what I have cited will answer my purpose of illustration.

The conclusion from the above statements is that no matter what the work is or how slowly it is being done by ordinary day work, we can, by determining the proper amount for a full day's work and offering a suitable compensation for its accomplishment, get a large number of men who will work at the increased speed in order to earn the reward which, for want of a better name, I have called a *bonus*.

The problem of determining a full day's work has been studied very thoroughly by Mr. Taylor, and in his paper on a "Piece Rate System" the subject of investigation has been gone into, and the necessity of educating the workman to follow the directions of the expert fully explained.

In my paper on the "Bonus System," I have shown how this educating can be done by Instruction cards, which serve also as permanent records of expert work. When my paper on the "Bonus System" was read last year, a number of people said the principles had been applied only to certain classes of work, and were not generally applicable. Soon after reading the paper referred to, the writer had the opportunity to go with the American Locomotive Company as Consulting Engineer, and realizing that if the principles were applicable to locomotive building they would be universally applicable, he accepted the position at once.

On account, however, of the large amount of preliminary work it was necessary to do, and the fact that all the plants of the combine except one had in satisfactory operation a system of piece or contract work, the field for the application of the Bonus System itself was limited to the one plant which was being operated on day work. I am able to say that in this plant the system has been successfully started, and not only are those men to whom it has been applied pleased, but their neighbors are pushing their machines harder than they ever did before, with the hope, evidently, that they will be chosen next. This is exactly the reverse of the effect produced by the ordinary piecework.

I should do the subject an injustice, however, if I should stop here, for a certain amount of work based on the principles of the Bonus System with Instruction cards is being done in other plants of the American Locomotive Company, and with such success that at the request of one of our superintendents I have recently been to a steel foundry furnishing him with castings to help them adopt the system to their work, with the hope on the part of our superintendent that he will get his steel castings with the same satisfaction that he now gets iron castings from his own foundry. These satisfactory results are gotten by keeping a daily balance of work done, on a sheet which serves the same end for a whole order that the Instruction card does for work on a single piece in one machine. By means of such a sheet, or series of sheets, we are enabled to compare graphically each day what has been done with what ought to have been done, and use our energies in pushing forward that which is behind. Naturally, such a sheet should be first introduced in the foundry and the forge, for to ship a locomotive on a certain day each casting and forging must be made a definite length of time before that day to allow for machining and erecting. Such a sheet for the foundry shows the date each casting should be made and is made, and a proper series of sheets for the machine and erecting shops show the route each piece should take, and the rate of progress it should make to arrive at the erecting shop in time to be incorporated without delay in the locomotive. This series of sheets may be likened to a train schedule, the Instruction cards being directions or time tables in detail for moving each portion of the work, the most important point being to avoid delays in making connections. Having gotten the schedule in such shape that we can make connections promptly, the next effort of the manufacturer is to shorten the time of each piece over its route as much as possible. This can be done by shortening the time on each element of the route as represented by an Instruction card, and by changing the route. Both of these operations in manufacturing are best done by experts, here again bearing out the analogy to a railroad, and new Instruction cards and schedules made out. The compensation set for following these Instruction cards must be made satisfactory to the workman, or the piece will not move promptly. The foreman who sees that the pieces pass through his territory on schedule time should also get additional compensation for efficiency. Thus the whole system produces harmony, the foremen being instructors and helpers rather than drivers, for their interest and that of the men is the same.

I do not pretend that what I have outlined is all in operation in one place; that would be more than the most sanguine could hope for as the result of less than a year's work, but I can point to nearly everything in operation somewhere, and the best feature of the whole subject is the hearty co-operation of all concerned when they have once grasped the idea and got it started. The foreman of a foundry where this has been started told me that his job was much more pleasant than it had been. The order in which his work was wanted had been fixed, and he was not bothered by people who thought that they ought to be served first. The foreman of the machine shop in the same plant told me that his running around had been cut in half.

In other words, exact instructions and records in place of judgment and memory will put responsibility where it belongs, and give credit where it is due. To sum up the subject then, the Bonus System consists simply in:

1. Having every problem, big or little, investigated by the best experts available.

2. Teaching the results of the expert investigation to those not capable of making it.

3. Rewarding such men as show themselves able and willing to carry out the methods adopted.

The direct results are: Increase in quantity of output; increase in economy of output; increase in efficiency of workmen.

An indirect result of the keeping the exact records that such a system demands is the moral effect, for in the daily balancing of accounts everything comes to light, and he who prefers darkness finds the conditions unpleasant.

As some will ask about the amount of clerical work needed, I might as well answer it now. The subject of shop records and shop accounting has until lately been given so little attention that the ordinary methods are very crude, for the reason that few shop men are expert bookkeepers, and few bookkeepers know the needs of the shop. By the adoption of modern methods all the clerical work I have indicated can usually be done by the Time and Cost Department in addition to their regular work, without additional clerks, and sometimes with fewer.

Mr. H. L. Gantt.—I want to say, in supplement to the foregoing written contribution, that the ideas expressed are the development of a great deal of work. Mr. Fred. Taylor began this work about twenty years ago. I myself have been doing it for about fifteen years. In one place I state that nearly all of the ideas which are suggested are in operation. That discussion was written some ten days ago. I can say now that I can erase the word "nearly," and say that all of those things are in operation somewhere, and the people who are using them are very much pleased with the methods which they are using, and are going to carry them out. I have with me a certain number of records, which show how the work is being done, and shall be very glad to explain to anybody who is interested.

Mr. Chas. F. McGill.—It seems to me that one question has been lost sight of in this discussion. My experience has been that with the piece-work system, as it is carried out to-day, production is restricted, and that we are trying for an increased production most of us will admit. To illustrate, from my own experience, in going through a shop under my charge, a man who had worked at the business probably thirty years, met me and remarked, "I have got two hours to loaf." This was about four o'clock. I naturally wanted to know how that came in, and he said, "This particular piece of work that I am doing is paid for at the rate of ten hours, everything has gone right with me to-day, and I have finished it in eight hours, and I know, and I think you know, that if I put in my time-card showing eight hours on that piece of work, the next time I get it I am going to get a price equal to eight hours," and I could not dispute him. As another illustration, I remember an instance where certain workers were told that they would be allowed to make more wages. When word was given out to different foremen that their employees could put in so much more in the way of wages, some of them remarked, "Well, we have heard that before; he could talk for several days, but we know we will be cut if we do it."

This is wrong in principle, and goes to prove the assertion that the piece-work system, as carried out in most places, tends to restrict production.

A workman does not need to have his prices cut many times before learning how much he is allowed to make, and governing himself accordingly.

When a man comes and asks, "How much am I allowed to put in for a day's work," it doesn't sound well?

I am satisfied where the piece-work system is carried out as I have described, by a change to the premium plan, production could be increased 20 per cent—I think there could be more of an increase made than that. The idea that we should be honest with our men is a good one. The fact that we are not is very plain to everybody. The men know it. The man knows that if he makes more than a certain proportion his price will be cut. If he knew that it would not, there would not be any object in his restricting production. His endeavor would be to get out all he could. This, we know, is not the case as the piece-work system is carried out.

Mr. F. H. Boyer.—There is one phase of this premium for piece work which has not been brought out in discussion. I am where I can see men who are sent out for the erection of work, engines and machinery. When the estimate is made up, there is a certain percentage put in for the cost of the erection. Now, when that erecting engineer goes out, you do not get a chance to see him for two weeks or two months, as the chance may occur, but if he comes back with his sheets showing a certain percentage less than he estimated for the erection of the work, he gets a per cent. of the amount saved. What does it mean? It means that that erecting foreman is watching his deliveries of freight. It means that he is constantly in consultation with the office. It means that he is employing only the best men. It means he does not permit them to smoke nor to idle their time away, and the contracting party gets the benefit of his watchfulness and he also gets the benefit. It has been a success.

Mr. H. H. Suplee.—In paragraph 5 of his paper, Mr. Richards calls attention to the faet that we do not use gift propositions in our own every-day transactions, and he suggests that we might use a bonus system for rewarding the grocer, or a premium plan of paying for beef, etc. I think Mr. Richards has got hold of the wrong end of that. The premium is the other way. People who want us to deal with them offer a lower price.

Col. E. D. Meier.—I think that both the writer of the paper, Mr. Richards, and some of the debaters take a somewhat Utopian view of the situation. Mr. Richards, probably on account of his long service in the same shop and his rise there, has created a feeling among the workmen which enables him to do things which perhaps the average man coming into a new shop, and especially a large shop, cannot do. We are very often in a situation where we cannot choose the men. We have to take the men as we find them. It is very difficult, especially in times of prosperity, to get more men. It is not a question of discharging a man and getting another. You cannot get another, and therefore, I think, the bonus system, as proposed and elucidated by Mr. Gantt, is the best solution of the problem. We cannot ignore the fact that labor unions tend to restrict production by making the pay of the poorest workman the same as that of the best, which kills individual ambition and energy. I think the bonus system a very practical way of meeting that.

Mr. Richards.—I would like to correct one assumption of the last speaker. My experience is of several shops of different character—not of one shop. I meant the American machine shop as a generic term. My experience has been in several shops of very different character.

Mr. Gantt.—A member has said he wants to know what has been spent on any job at the end of the year. I want to know it the next day. We cannot correct it if it is away behind. I want a daily balance of what goes on. I want to know how much was spent yesterday, and I am so far encouraged as to have a man tell me in the last two or three days that he hopes in the next three or four months that he will be able to tell what money has been spent in the whole plant on miscellaneous work by noon the next day, and what it has been spent for. Mr. Rogers says he has instituted the premium system here and there, and as soon as he left it was gone—all wiped out. I have to say that I have been visiting eight plants during the last year, and in four of those plants some of these principles which I have illustrated have been put in operation. Personally I have not made a stroke. I object to doing a single bit of it myself. I insisted that the people should understand what it meant, and that they should do it if they wanted it. I did not have the authority to say, "You gentlemen must do this." I was allowed to go around and see if I could do anything. They told me at first that they did not believe in what I was talking about. Nobody was interested. Finally one concern said, "We are having trouble with our foundry." I said, "All right, gentlemen, then try the daily balance that I suggested in your foundry." They tried it in their foundry work, and in two months they made the statement that they are going to extend the same principles throughout the works, and asked me if I would not go to the steel foundry where they are getting the steel castings, and see if I could not persuade those people to do the same thing in order that they may get their steel castings when they want them. That is the condition of affairs, and it is because I do not attempt to do these things myself—if I am part of the organization all right, but if I am not part of the organization, it must be done through the organization as it exists. If those people cannot understand it, they had better not touch it. If they understand the principles and find anything which is useful to them, then they will use it; otherwise not.

Mr. W. S. Rogers.—I would like to advise Mr. Gantt that there are hundreds of concerns, large and small, in this country to-day who do not use his system, and they can know an hour after a piece of work is done or a machine built, just what it has cost, and they can find just what the loss was either in material or anything else. Then he says he has been to eight concerns. Probably the members do not know that these eight concerns are all owned by one company. There are many concerns running forty or fifty men that cannot afford to pay a $10,000 expert to run their business and have anything left. Now, the premium plan is a good thing in its place, and the bonus plan is a good thing in its place; but I will tell you a better plan that will wipe the labor union problems out of existence and make your men the best workers that ever were put on the face of the earth : Permit every man to own a share of the stock or an interest, if it is only $20.00 worth, and there is no force, monopoly or combination on earth to drive you out of business. And to illustrate that, look at the Ivorydale Soap Works at Ivorydale. Our Society went there a few years ago, but we did not learn the lesson from the workmen and workwomen there. Every woman and girl was interested, and there was nothing lost. The same thing holds good in machine shops, and there are machine shops run that way to-day where the humblest worker has an interest. The minute you turn a shop to that plan, labor agitators may come outside with all the brass bands and ammunition they possess, and cannot get a man to go out, because he is a part owner. That is the way to succeed in making dividends and wiping out the antagonism of labor unions.

Mr. G. I. Alden.—I wanted to ask one question for information regarding the premium system. Is it not customary in adopting the premium system to have such knowledge of the time which should be required to get out the work that you can say to the workmen, when you offer them the premium : "Now, we will do this, and we won't cut you for a year or two years," and isn't that an important part of the consideration? So that the workman, when he enters into it and tries to do his best, will not have the feeling that as quick as he succeeds in cutting the time down, the price will be cut. Is not this an important element in the premium system if you are to get the most good out of it?

Mr. Fred J. Miller.—I think I can answer that question. I think it is of the essence of the premium system not to cut the rate at all—not merely within a year or two years, but never, unless there is a change in the system of producing the piece which will give a reasonable ground for a new rate. It has been pointed out that the vital principle of the premium system is to have it understood by the men that the terms upon which the work is done will not be changed ; otherwise they will restrict their production just as they do in piece work.

Mr. F. A. Halsey (contributed after the meeting).—The weakness of Mr. Richards's logic lies in his italicized clause in paragraph 12, "As he certainly is paid in that way for all the product of his shop." This is true for the time being, but it has never been and will never be true for a long period of time. The history of the past is a record of falling prices, and the future can only repeat the experiences of the past. Looked at in this way, the principal of equity on which Mr. Richards relies turns against him, as it certainly is not equitable for an employer to pay the same piece rates for his product, after a material fall in the selling price, that he paid before.

This has been the basis of my entire argument against the piece-work system and for the premium system. I hold that cuts in the rates are inherent in the piece-work system, because of the inevitable fall in prices as time goes on. No appeal to principles can justify permanent piece rates in the face of a fall in selling prices.

The matter may be summed up by saying that the premium plan looks into the future, while the piece-work system does not. It must be remembered also that all men gauge the value of their services by the income which they give them—this income being measured in dollars per day, per month or per year, as the case may be. No workman measures his income by the rate per piece which he receives for his work, but by the amount which he receives per day or per week, and a system which gives the workman a reward for increased efforts which, by his own acceptance of it and without any trace of compulsion, he admits to be fair, cannot be called inequitable.

*Mr. Richards.**—This "discussion" of my paper may be styled rather a perfunctory "sitting down" upon it. With such an unanimous disposition to condemn it as a whole, it would seem that some fault might have been found with the details of it. No one suggests that I misrepresent the premium plan as to the way in which the introduction is usually proposed to the workman. If anyone thinks it an honest and business-like proposition, it is useless for me to try to argue the matter with him further.

The continued assumption of the rate-fixers is that the one thing always to be done is to reduce the wage cost per unit of

---

* Author's closure, under the Rules.

production. Mr. Halsey assumes this with the rest, and claims that permanent piece-work prices cannot do this, which is evident, but that premium plan prices can and do, which is not evident. If a man accepts the premium plan in good faith and does his best under it, he soon reaches his speed limit, and then the premium plan rates are just as fixed as piece-work rates, and can do no more to help the manufacturer to meet the falling market. If prices fall sufficiently, the manufacturer must cut his wages whether determined by day-work, piece-work or by either of the gift propositions. Prices go up as well as down, and the workman has a right to share in the fruits of prosperity. The discussion ignores this absolutely.

No. 966.*

HEAT RESISTANCE, THE RECIPROCAL OF HEAT CONDUCTIVITY.†

BY WILLIAM KENT, NEW YORK.
(Member of the Society.)

1. During a recent study of the heat-conducting power of various substances used for heat insulation, especially in cold storage warehouses, the writer discovered that the comparison of results obtained by different experimenters would be facilitated if these results were reduced to a common basis of coefficients of heat resistance, instead of being expressed, as is usual, in the number of British thermal units transmitted per hour, or per day, by each square foot of surface per degree of difference of temperature of the air adjoining the two surfaces.‡

---

* Presented at the New York meeting (December, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

† For further discussions on this and similar topics consult *Transactions* as follows:

No. 421, vol. xii., p. 174: "Heat Transmission Through Cast Iron Plates Pickled in Nitric Acid." R. C. Carpenter.

No. 461, vol. xii., p. 1014: "Heat Transmission Through Plates Pickled in Nitric Acid." Daniel Royse.

‡ The use of coefficients of heat resistance instead of those of conductivity is suggested by Rankine (Steam Engine, p. 258). He says: "The rate of conduction through a flat layer of any uniform thickness is simply proportional directly to the difference between the temperatures of the two faces of the layer and inversely to its thickness, a principle expressed as follows:

$$g = k \frac{T' - T}{x}$$

where T' and T are the temperatures at the two faces of the layer and x its thickness—(k being the coefficient of internal conductivity). For reasons which will afterwards appear, it is convenient in cases of this kind instead of the conductivity, k itself, to use its reciprocal, which may be called the *internal thermal resistance* of the substance. The total internal thermal resistance of a plate consisting of layers of different substances may be found by adding together the resistances of the several layers. The rate of *external conduction* through the bounding surface between a solid body and a fluid is approximately proportional

2. The use of these figures representing *resistance* instead of those representing *conductivity* is analogous to the usual practice in electrical calculations, the chief advantage being that resistances in series may be added together to obtain total resistance, while the conductance of several wires or other bodies acting in series cannot be added to obtain the total conductance. Thus, if R_1 and R_2 are the resistances of two wires arranged in series, or one after the other, their total resistance is $R_1 + R_2$. If c_1 and c_2 are the conductances of these two wires, or the reciprocal of the resistances, $= \frac{1}{R_1}, \frac{1}{R_2}$, respectively, their total conductance is not $c_1 + c_2$, but $1 \div \left(\frac{1}{c_1} + \frac{1}{c_2}\right)$.

3. The meaning of this, as applied to heat conductance, may be made clear by considering the following hypothetical case. Suppose that in testing the heat-conducting power of a certain substance, say a sheet of cardboard, we find that its conductivity, expressed in British thermal units per square foot per hour per degree of difference of temperature is 0.8, and that a sheet of felt tested in the same way gives the figure 0.4; placing a felt between two boards we obtain 0.2; two felts between three boards, 0.1143; three felts between four boards, 0.08; four felts between five boards, 0.0615. We can find no satisfactory relation between the several figures by adding or subtracting them, but by taking

---

to the difference of temperature when that is small. The rate of external conduction may be expressed by dividing the difference of temperature by a coefficient of *external thermal resistance* depending on the nature of the substances, and also on their temperatures. Let the values of that coefficient, for the two surfaces of a given plate, be denoted by σ', σ respectively; let x be the thickness of the plate in inches as before, and ζ its coefficient of internal thermal resistance; then the total thermal resistance of the plate and of its two external surfaces is

$$\sigma' + \sigma + \zeta x;$$

and the rate of conduction through it is

$$q = \frac{T' - T}{\sigma' + \sigma + \zeta x}$$

where T', T are now the temperatures, not of the two surfaces of the plate, but of the two fluids which are respectively in contact with its two surfaces.

their reciprocals we find they are entirely in harmony, as is shown in the following table:

	Conductivity.	Difference.	Reciprocal.	Difference
1 sheet cardboard	0.8	0.0	1.25	0.0
1 sheet felt..................	0.4	0.4	2.5	1.25
2 cardboards, 1 felt	0.2	0.2	5.0	2.5
3 " 2 "	0.1143	0.0857	8.75	3.75
4 " 3 "	0.08	0.0343	12.50	3.75
5 " 4 "	0.0615	0.0185	16.25	3.75

4. The last column shows that the resistance to transmission of heat of any combination of these elements is simply the sum of the separate resistances of the several elements. Of course such a perfectly harmonious result can never be expected in actual tests of heat insulators, such as may be obtained in tests of electrical resistances, for the reasons: (1) That it is impossible to obtain uniform conditions in and on the two surfaces of any non-conductor of heat which is exposed to the atmosphere, and (2), that in an assemblage of elements such as described some of the surfaces are in contact with other elements, while others are exposed, this difference of conditions making a great difference in the resistance of the surface to transfer of heat.

5. Authorities on the subject of heat transmission generally agree that the resistance to the passage of heat through a plate consists of three separate resistances; viz., the resistances of the two surfaces and the resistance of the body of the plate, which latter is proportional to the thickness of the plate. It is probable also that the resistance of the surface differs with the nature of the body or medium with which it is in contact. Thus a very rough surface on a metal plate would be likely to transfer more heat to adjacent air than a smooth surface would, since it has a greater area in actual contact with the air, while two rough surfaces of metal touching each other would transmit from one to the other less heat than two smooth surfaces.

6. A complete set of experiments on the heat-resisting power of heat-insulating substances should include an investigation into the difference in surface resistance when a surface is in contact with air and when it is in contact with another solid body. Suppose we find that the total resistance of a certain non-conductor may be represented by the figure 10, and that similar pieces all give the same figure. Two pieces in contact give 16. One piece of half

the thickness of the others gives 8. What is the resistance of the surface exposed to the air in either piece, of the surface in contact with another surface, and of the interior of the body itself? Let the resistance of the material itself, of the regular thickness, be represented by A, that of the surface exposed to the air by a, and that of the surface in contact with another surface by c.

7. We then have for the three cases,

Resistance of one piece	$A + 2a = 10$
" of two pieces in contact	$2A + 2c + 2a = 16$
" of the thin piece..................	$\frac{1}{2}A + 2a = 8$

These three equations contain three unknown quantities. Solving the equations we find $A = 4$, $a = 3$, and $c = 1$. Suppose that another experiment be made with the two pieces separated by an air space, and that the total resistance is then 22. If the resistance of the air space be represented by s we have the two equations. Resistance of one piece, $A + 2a = 10$; resistance of two pieces and air space, $2A + 4a + s = 22$, from which we find $s = 2$. Having these results we can easily estimate what will be the resistance to heat transfer of any number of layers of the material, whether in contact or separated by air spaces.

8. The writer has computed the figures for heat resistance of several insulating substances from the figures of conducting power given in a table published by Mr. John E. Starr, in a paper on "Insulation for Cold Storage," published in *Ice and Refrigeration* for November, 1901. Mr. Starr's figures are given in terms of the British thermal units transmitted per square foot of surface per day per degree of difference of temperature of the air adjacent to each surface. The writer's figures, those in the last column of the table given herewith, are calculated by dividing Mr. Starr's figures by 24, to obtain the hourly rate, and then taking their reciprocals. They may be called "coefficients of heat resistance" and defined as the reciprocals of the British thermal units per square foot per hour per degree of difference of temperature.

HEAT CONDUCTING AND RESISTING VALUES OF DIFFERENT INSULATING MATERIALS.

Insulating Material.	Conductance, B.T.U. per sq. ft. per day per degree of difference of temperature.	Coefficient of heat resistance.
1. $\frac{5}{8}$-in. oak board, 1-in. lampblack, $\frac{7}{8}$-in. pine board (ordinary family refrigerator)................	5.7	4.21
2. $\frac{7}{8}$-in. board, 1-in. pitch, $\frac{7}{8}$-in board	4 89	4.91
3. $\frac{7}{8}$-in, board, 2-in. pitch, $\frac{7}{8}$-in. board	4.25	5.65
4. $\frac{7}{8}$-in. board, paper, 1-in. mineral wool, paper, $\frac{7}{8}$-in. board	4.6	5.22
5. $\frac{7}{8}$-in. board, paper, $2\frac{1}{2}$-in. mineral wool, paper, $\frac{7}{8}$-in. board	3.62	6.63
6. $\frac{7}{8}$-in. board, paper, $2\frac{1}{2}$-in. calcined pumice, $\frac{7}{8}$-in. board....................................	3.38	7.10
7. Same as above, when wet	3.90	6.15
8. $\frac{7}{8}$-in. board, paper, 3-in. sheet cork, $\frac{7}{8}$-in. board	2.10	11.43
9. Two $\frac{7}{8}$-in. boards, paper, solid, no air space, paper, two $\frac{7}{8}$-in boards...........................	4.28	5.61
10. Two $\frac{7}{8}$-in boards, paper, 1 air space, paper, two $\frac{7}{8}$-in. boards..................................	3.71	6.47
11. Two $\frac{7}{8}$-in. boards, paper, 1-in. hair felt, paper, two $\frac{7}{8}$-in. boards	3.32	7.23
12. Two $\frac{7}{8}$-in. boards, paper, 8-in. mill shavings, paper. paper, two $\frac{7}{8}$-in. boards.....................	1.35	17.78
13. The same, slightly moist	1.80	13.33
14. The same, damp	2.10	11.43
15. Two $\frac{7}{8}$-in. boards, paper, 3-in. air, 4-in. sheet cork, paper, two $\frac{7}{8}$-in. boards.....................	1.20	20.00
16. Same, with 5-in. sheet cork	0.90	26.67
17. Same, with 4-in. granulated cork	1.70	14.12
18. Same, with 1-in. sheet cork	3.30	7.27
19. Four double $\frac{7}{8}$-in. boards (8 boards), with paper bet. three 8-in. air spaces	2.70	8.89
20. Four $\frac{7}{8}$-in. boards, with three quilts of $\frac{1}{4}$-in. hair bet. papers separating boards................	2.52	9.52
21. $\frac{7}{8}$-in. board, 6-in. patented silicated strawboard, finished inside with thin cement	2.48	9.68

9. Analyzing some of the results given in the last column of the table, we observe that, comparing Nos. 2 and 3, 1 inch added thickness of pitch increased the coefficient 0.74; comparing Nos. 4 and 5, $1\frac{1}{2}$ inches of mineral wool increased the coefficient 1.11. If we assume that the 1 inch of mineral wool in No. 4 was equal in heat resistance to the additional $1\frac{1}{2}$ inches added in No. 5, or 1.11 reciprocal units, and subtract this from 5.22, we get 4.11 as the resistance of two $\frac{7}{8}$-inch boards and two sheets of paper. This

would indicate that one $\frac{7}{8}$-inch board and one sheet of paper give nearly twice as much resistance as 1 inch of mineral wool. In like manner any number of deductions may be drawn from the table, and some of them will be rather questionable, such as the comparison of No. 15 and No. 16, showing that 1 inch additional sheet cork increased the resistance given by four sheets 6.67 reciprocal units, or one-third the total resistance of No. 15. This result is extraordinary, and indicates that there must have been considerable differences of conditions during the two tests.

10. For comparison with the coefficients of heat resistance computed from Mr. Starr's results we may take the reciprocals of the figures given by Mr. Alfred R. Wolff (Kent's "Mechanical Engineers' Pocket-Book," p. 534), as the result of German experiments on the heat transmitted through various building materials, as below:

K = B.T.U. transmitted per hour per sq. ft. of surface, per degree F difference of temperature.

C = heat resistance = reciprocal of K.

	Thickness.	K.	C.	Difference.
Brick wall.	4-in.	0.68	1.47	
				0.70
	8-in.	0.46	2.17	
				0.86
	12-in.	0.32	3.03	
				0.82
	16-in.	0.26	3.85	
				0.70
	20-in.	0.23	4.55	
				0.45
	24-in.	0.20	5.00	
				0.75
	28-in.	0.174	5.75	
				0.92
	32-in.	0.15	6.67	
				1.08
	36-in.	0.129	7.75	
				0.95
	40-in.	0.115	8.70	
Wooden beam construction, planked over or ceiled:				
As flooring		0.083	12.05	....
As ceiling		0.104	9.71	....
Fireproof construction, floored over: As flooring		0.124	8.06	....
As ceiling		0.145	6.90	....

Single window	1.030	0.97	....
Single skylight	1.118	0.89	....
Double window	0.518	1.93	...
Double skylight	0.621	1.61	....
Door	0.414	2.42	....

11. The irregularity of the differences of C for each increase of 4 inches in thickness of the brick walls indicates a difference in the conditions of the experiments from which the figures were derived. The average difference of C for each 4 inches of thickness is about 0.80. Using this average difference to even up the figures we find the value of C is expressed by the approximate formula $C = 0.70 + 0.20\,t$, in which t is the thickness in inches. The revised values of C, computed by this formula, and the corresponding revised values of K are as follows:

	Thickness.	C.	K.	K, original figures.	Difference.
Brick wall.	4-in.	1.50	0.667	0.68	0.013
	8-in.	2.30	0.435	0.46	0.025
	12-in.	3.10	0.323	0.32	0.003
	16-in.	3.90	0.256	0.26	0.004
	20-in.	4.70	0.213	0.23	0.017
	24-in.	5.50	0.182	0.20	0.018
	28-in.	6.30	0.159	0.174	0.015
	32-in.	7.10	0.141	0.15	0.009
	36-in.	7.90	0.127	0.129	0.002
	40-in.	8.70	0.115	0.115	0.0

12. In conclusion the writer would propose to engineers and others who have to make tests in which heat transmission is involved the adoption of a standard for expressing heat resistance or the heat insulating power of various substances as follows:

The coefficient of heat resistance of a substance is equal to unity divided by the number of British thermal units transmitted in one hour by a slab 1 square foot in area and 1 inch thick, per degree Fahrenheit of difference of temperature between the two faces of said slab, both surfaces being exposed to still air.

It should be noted that the coefficient of resistance thus defined will be approximately a constant quantity for a given substance under certain fixed conditions, only when the difference of temperature of the air on its two sides is small—say less than 100 degrees Fahrenheit. When the range of temperature is great, experiments on heat transmission indicate that the quantity of heat transmitted varies, not directly as the difference of temperature, but as the square of that difference. In this case a coefficient of resistance with a different definition may be found—viz., that obtained from the fomula $a=\frac{(T-t)^2}{q}$, in which a is the coefficient, $T—t$ the range of temperature, and q the quantity of heat transmitted, in British thermal units per square foot per hour.

13. The subject of the heat-insulating power of different substances is of immense importance in refrigerating work, and it is to be hoped that when further experiments with such substances are made their results may be reported in the manner here suggested, and that conclusions be drawn by the experimenters from the reciprocal values or "coefficients of heat resistance" here described.

No. 967.*

AN ANALYSIS OF THE "COMMERCIAL" VALUE OF WATER-POWER PER HORSE-POWER PER ANNUM.†

BY A. F. NAGLE, MONTCLAIR, N. J.
(Member of the Society.)

1. THE writer recently testified in court as to the value of water-power per horse-power per annum in a manner that may be of interest to our membership. The subject-matter has been discussed heretofore in our Society, but I am not aware that precisely the same analysis has been given before. The problem is quite a familiar one to New England engineers. The river-flow is assured to certain abutting parties by old legislative grants, and is usually used for power purposes. Any town or city taking water from this stream is liable for damages incurred by reducing the available power of said stream of water. The amount of power existing in the stream at each mill, expressed in horse-power as well as the amount taken, or diverted, by the city, and affecting the particular mills, is a problem for hydraulic engineers which I do not take up; but the value of the water-power at each mill is a problem which I have attempted to solve. I have formulated my studies under three theorems, which I believe express the true principles under which the problem can be solved with as much certainty as the cost of a steam-power.

2. *Theorem* 1. The value of water-power, when of ample capacity for a specific purpose, does not exceed the cost of what a competing power (steam or gas engine) can be installed and operated for at the same locality.

---

* Presented at the New York meeting (December, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

† For further discussion on this topic consult *Transactions* as follows:

No. 332, vol. x., p. 499: "Comparative Cost of Steam and Water-power." Chas. H. Manning.

No. 360, vol. xi., p. 108: "Cost of Steam and Water-power." Chas. T. Main.

No. 471, vol. xiii., p. 140: "Value of a Water-power." Chas. T. Main.

No. 848, vol. xxi., p. 590: "On the Value of a Horse-power." Geo. I. Rockwood.

Theorem 2. When a water-power is insufficient for a specific purpose, due to the varying flow at different seasons of the year, and its limited amount, then its value is reduced from that established by Theorem 1, by the cost of (installing and) operating a steam plant to make good this insufficiency.

Theorem 3. The "damages" to be paid annually (or capitalized at —— per cent. if made in one payment) for a given amount of diverted water-power is the value of the water-power as found by Theorem 2, plus the depreciation in the value of the remaining water-power.

3. The cost of power is an element in all productive industries, and whether it be a large or small element, the mill (we will call it) demands a certain amount of power, the cost of which, if a steam plant, can be calculated quite closely, probably within 10 per cent. It is the interest of the mill owner to obtain this power at the least possible cost to himself, and he stands in the position of a buyer of power before the power-producing public. Two sellers may offer him power—a steam-power producer, or a water-power producer. Because the mill owner in New England is generally also a water-power owner, does not change the relation of the power consumer to the power producer, a buyer and a seller, and for a clear understanding of this complex problem, it is absolutely necessary to separate the two parties in any analysis that may be applied to the problem under consideration.

4. The annual cost of steam-power per horse-power, including every item except land, can be calculated by an experienced engineer for any particular locality with reasonable accuracy. In Tables I. and II. I have given my estimates of engine plants ranging from 50 horse-power to 500 horse-power, single-condensing engines; and from 400 horse-power to 1,500 horse-power compound-condensing engines located along the Blackstone River, New England. These estimates are generally large, but as the items appear both in the minuend and subtrahend of the calculation, the remainder (resulting in the value of the water-power) is not so seriously affected thereby. The result, however, of these larger figures for steam-power is to increase the value of the water-power. The items comprising the tables are all so well known to engineers that it is needless for me to comment upon them. Nor is it so much my purpose to establish the accuracy of these particular items, or their results, as it is to establish a principle, or method, of calculating the value of a water-power

for power purposes, and thereby take the problem out of the domain of prejudiced guesswork.

TABLE I.

ANNUAL COST OF STEAM-POWER PER INDICATED HORSE-POWER.

Compound Condensing Engine.

HORSE-POWER.	400	500	600	700	800	900	1,000	1,200	1,500
	$	$	$	$	$	$	$	$	$
Cost of Plant per I.H.P.	64 00	60 00	57 50	56 00	55 50	55 00	54 60	54 00	53 00
Annual Interest, etc., @ 10 p. c. per I.H.P...	6 40	6 00	5 75	5 60	5 55	5 50	5 46	5 40	5 30
Cost of Banking (no heating) Repairs, Supplies, Engineer, etc., per I.H.P...........	7 30	7 60	7 75	7 80	7 95	7 70	7 55	7 50	7 50
Annual (3,060 hrs.) Cost of Coal @ $4.50 per long Ton per I.H.P..	12 30	11 40	10 50	9 85	9 50	9 30	9 25	9 25	9 20
Total Annual Cost per I.H.P.	26 00	25 00	24 00	23 25	23 00	22 50	22 26	22 15	22 00

TABLE II.

ANNUAL COST OF STEAM-POWER PER INDICATED HORSE-POWER.

Simple Condensing Engine.

HORSE-POWER.	50	75	100	150	200	250	300	400	500
	$	$	$	$	$	$	$	$	$
Cost of Plant per I.H.P.	90 00	75 00	65 00	57 00	51 00	47 00	45 00	43 00	42 00
Annual Interest, etc. @ 10 p. c. per I.H.P....	9 00	7 50	6 50	5 70	5 10	4 70	4 50	4 30	4 20
Cost of Banking (no heating) Repairs, Supplies, Engineer, etc., per I.H.P...........	9 00	8 50	8 20	8 30	8 60	8 30	7 90	7 85	7 80
Annual (3,060 hrs.) Cost of Coal @ $4.50 per long Ton per I.H.P...	25 00	22 00	20 00	17 00	15 30	15 00	14 60	13 85	13 00
Total Annual Cost per I H.P.	43 00	38 00	34 70	31 00	29 00	28 00	27 00	26 00	25 00

5. *Theorem* 1 is almost a self-evident proposition. No mill owner as a buyer of power will pay more for water-power than he can install and operate a steam plant for. He would not even give as much as that, because if he had water-power only, he would have to install a boiler plant for heating and other auxiliary uses; while if he had a steam plant, he could supply himself with this additional steam at a comparatively small cost. For present purposes, however, I shall neglect this fact.

6. *Theorem* 2 is not quite so obvious. Very few water-powers are of sufficient power to supply the large mills they drive with ample power every day in the year. At times there is an excess, and at other times it is quite insufficient. It is at this point that a clear understanding must be had of the relation of the mill owner to the water-power owner. It is not the business of the mill owner to meddle with the problem of this varying and insufficient water supply. That difficulty belongs entirely to the water-power owner. In order to make the water-power commercially available, in order to give it any value at all to the purchaser of power, in order to give it what it has been pleased to call "a market value," "a commercial value," he must supplement the fluctuating water-power with steam-power. The maximum possible price obtainable for the combined steam and water-power has been fixed by the cost of a single steam plant. Hence the less the steam-power costs him the more he will get for his water-power. This will be more fully illustrated by detailed calculations hereafter.

7. *Theorem* 3. This theorem is perhaps more theoretical than practical, for in few cases is the quantity of water diverted from a stream sufficiently large to affect perceptibly the quantity remaining. It is, however, a fact that repeated diversions constantly diminish the value of the remaining power; and it is proper that this depreciation of the remaining power should be paid for at each diversion. This would seem to be a principle of equity, and I have investigated the application to a particular case upon a rather extravagant hypothesis.

8. To illustrate the practical application of the theorems here advanced, I have selected six mills and their power diagrams from the testimony in the suit:

First, the river flow in horse-power for every month in the year is established at each mill by the hydraulic engineers employed in the suit. The amount of the diverted power at each mill is also given by said engineers, but is too small to appear in the diagrams (Figs. 79–84). The amount of power required to operate the mill, and the wheel capacity, are given by the mill owner.

Referring to Fig. 79, the power of the river flow is seen to vary

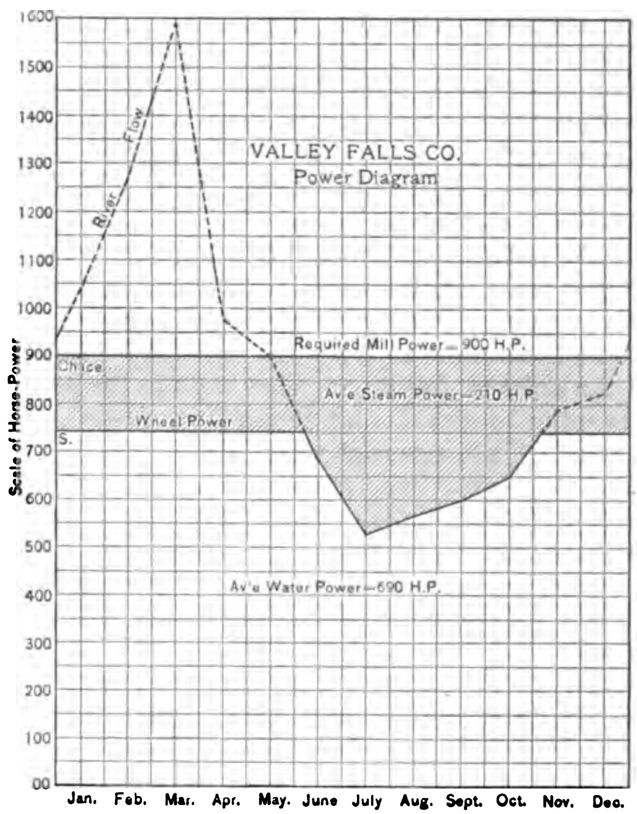


FIG. 79.

greatly. This mill requires an average of 900 horse-power per annum. The water wheel is of only 743 horse-power, and the mean annual water-power is 690 horse-power, requiring a steam-power of 210 horse-power to give the 900 horse-power to the mill. The low stage of the river is such that a 370 horse-power steam plant will be required at times.

9. The following is a detailed calculation for obtaining the value of the water at the several mills.

NO. 1.—VALLEY FALLS COMPANY.

Required mill-power	900 Horse-power.	
Average water-power	690 "	
Average steam-power	210 "	
Maximum steam-power	370 "	
Time engine runs	12 months.	
Full annual cost of 900 H.-P. C. C. plant @ $22.50		$20,250
Annual interest, etc., 370 H.-P. S. C. @ $4.40	$1,628	
Annual supplies, etc., 370 H.-P. S. C. @ $7.85	2,904	
Annual coal, 210 H.-P. S. C. @ $14.00	2,940	
Total cost of 210 H.-P. steam	$7,472—	7,472
Cost per H.-P.	$35.60	
Value of 690 H.-P. water		$12,778
Value of 1 H.-P. water	$18.52	

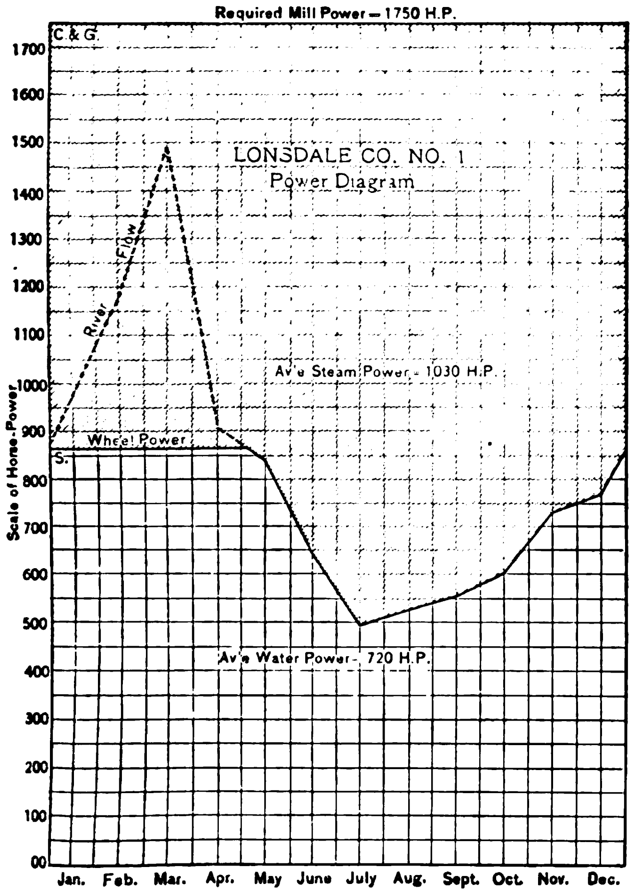


FIG. 80.

NO. 3.—LONSDALE COMPANY, NO. 1.

Required mill-power	1,750 Horse-power.		
Average water-power	720 "		
Average steam-power	1,030 "		
Maximum steam-power	1,260 "		
Time engine runs	12 months.		
Full annual cost of 1,750 H.-P. C. C. plant @ $22.00			$38,500
Annual interest, etc., 1,260 H.-P. C.C. @ $5.40		$6,804	
Annual supplies, etc., 1,260 H.-P. C. C. @$7.50		9,450	
Annual coal, 1,030 H.-P. C. C. @ $9.50		9,785	
Total cost of 1,030 H.-P. steam		$26,039—	26,039
Cost per H.-P.	$25.27		
Value of 720 H.-P. water			12,461
Value of 1 H.-P. water	$17.30		

NO. 4.—LONSDALE COMPANY, NO. 4.

Required mill-power	1,000 Horse-power.		
Average water power	444 "		
Average steam-power	556 "		
Maximum steam-power	700 "		
Time engine runs	12 months.		
Full annual cost of 1,000 H.-P. C. C. plant @ $22.25			$22,250
Annual interest, etc., 700 H.-P. C. C. @ $5.60		$3,920	
Annual supplies, etc., 700 H.-P. C. C. @ $7.80		5,460	
Annual coal, 556 H.-P. C. C. @ $10.00		5,560	
Total cost of 556 H.-P. steam		$14,940—	14,940
Cost per H.-P.	$26.87		
Value of 444 H.-P. water			7,310
Value of 1 H.-P. water	$16.46		

NO. 5.—SAMOSET COMPANY.

Required mill-power	1,100 Horse-power.		
Average water-power	860 "		
Average steam-power	240 "		
Maximum steam-power	500 "		
Time engine runs	12 months.		
Full annual cost of 1,100 H.-P. C. C. plant @ $22.20			$24,420
Annual interest, etc., 500 H.-P. C. C. @ $6.00		$3,000	
Annual supplies, etc., 500 H.-P. C.C. @ $7.60		3,800	
Annual coal, 240 H.-P. S. C. @ $11.40		2,736	
Total cost of 240 H.-P. steam		$9,536—	9,536
Cost per H.-P.	$40.00		
Value of 860 H.-P. water			$14,884
Value of 1 H.-P. water	$17.31		

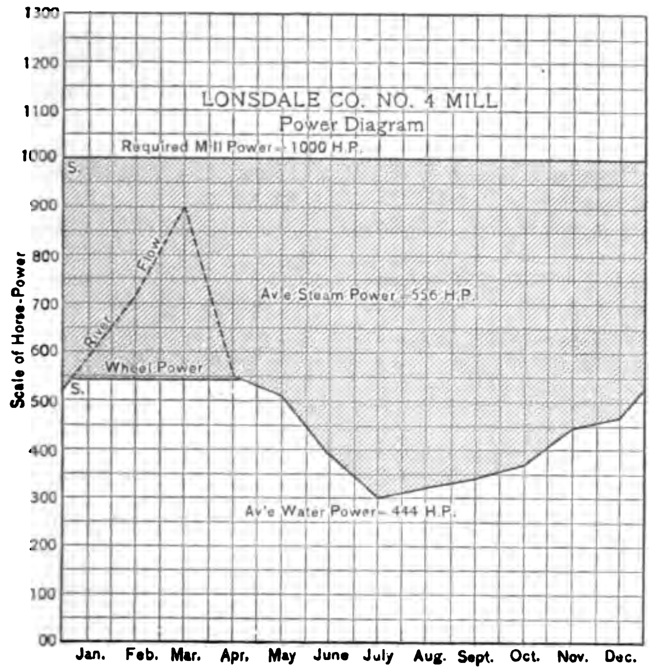


FIG. 81.

NO. 9.—DEXTER YARN COMPANY.

Required mill-power	280 Horse-power.		
Average water-power	115 "		
Average steam-power	165 "		
Maximum steam-power	210 "		
Time engine runs	12 months.		
Full annual cost of 280 H.-P. S. C. plant @ $27.50			$7,700
Annual interest, etc., 210 H.-P. S. C. @ $5.00		$1,050	
Annual supplies, etc., 210 H.-P. S. C. @ $8.55		1,796	
Annual coal, 165 H.-P. S. C. @ $12.25		2,516	
Total cost of 165 H.-P. steam		$5,362—	5,362
Cost per H.-P.	$32.50		
Value of 115 H.-P. water			2,338
Value of 1 H.-P. water	$20.33		

NO. 14.—PAWTUCKET ELECTRIC COMPANY.

This mill must be calculated upon a basis of 24 hours a day and 365 days a year, all others having been calculated upon 10 hours a day and 306 days in the year.

Required mill-power (1,200–1,400)		1,300	Horse-power.
Average water-power		550	"
Average steam-power		750	"
Maximum steam-power		1,200	"
Time engine runs	12 months.		
Full annual cost of 1,300 H.-P. C. C. plant @ $53.33			$69,329
Annual interest, etc., 1,200 H.-P. C. C. @ $5.40		$6,480	
Annual supplies, etc., 1,200 H.-P. C. C. @ $21.46		25,752	
Annual coal, 750 H.-P. C. C. @ $26.47		19,852	
Total cost of 750 H.-P. steam		$52,084—	52,084
Cost per H.-P.	$69.44		
Value of 550 H.-P. water			17.245
Value of 1 H.-P water	$31.35		

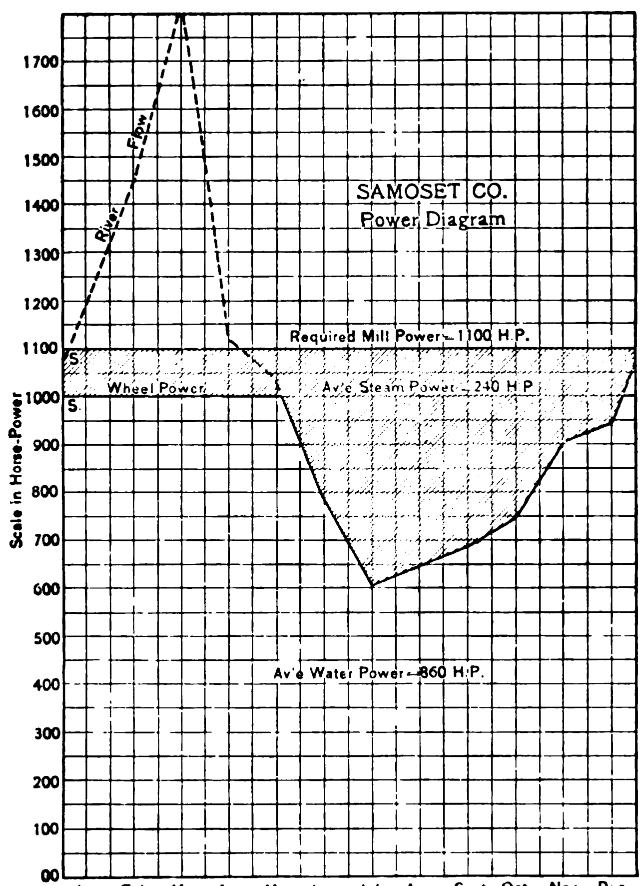


FIG. 82.

If made upon a 10-hour basis and 306 days a year, the calculation would stand as follows:

Full annual cost of 1,300 H.-P. C. C. plant @ $22.00			$28,600
Annual interest, etc., 1,200 H.-P. C. C. @ $5.40		$6,480	
Annual supplies, etc., 1,200 H.-P. C. C. @ $7.50		9,000	
Annual coal, 750 H.-P. C. C. @ $9.25		6,937	
Total cost of 750 H.-P. steam		$22,417—	22,417
Cost per H.-P.	$30.00		
Value of 550 H.-P. water			6,183
Value of 1 H.-P. water	$11.24		

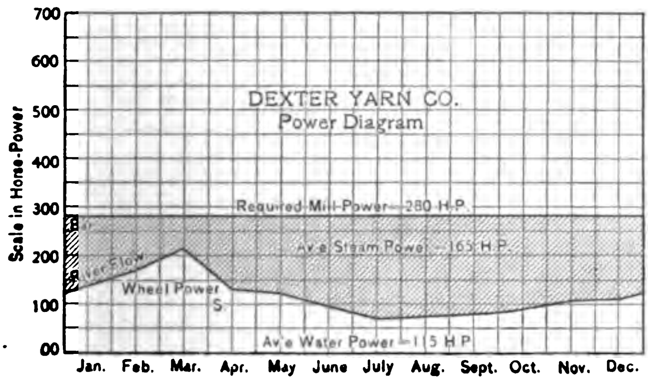


FIG. 83.

10. Table III. is a summary of the preceding calculations.

TABLE III.

VALUE OF WATER-POWER AT DIFFERENT MILLS AND ALSO WHAT IT WOULD HAVE BEEN WORTH IF IT HAD BEEN A FULL POWER.

Mill No.	Required Mill Power H.-P.	Average Water Power H.-P.	Average Steam Power H.-P.	Maximum Engine-Power H.-P.	Value of Full Power (Water).	Value of Partial Water-Power.
1	900	690	210	370	$22.50	$18.51
3	1,750	720	1,030	1,260	22.00	17.30
4	1,000	444	556	700	22.25	16.46
5	1,100	860	240	500	22.20	17.31
9	280	115	165	210	27.50	20.33
14	1,300	550	750	1,200	*53.33	*31.35
					†22.00	†11.24

* This plant is an electric power station and was calculated upon a basis of running twenty-four hours a day and 365 days a year. All the others were calculated upon running 10 hours a day and 306 days a year.

† Upon a 10-hour basis, 306 days a year.

Maximum Efficiency of a Water-power Plant.

11. Referring again to Fig. 79, it is quite evident that a larger wheel-power would have been conducive to a greater value of the water-power.

For the purpose of ascertaining the greatest value of a water-

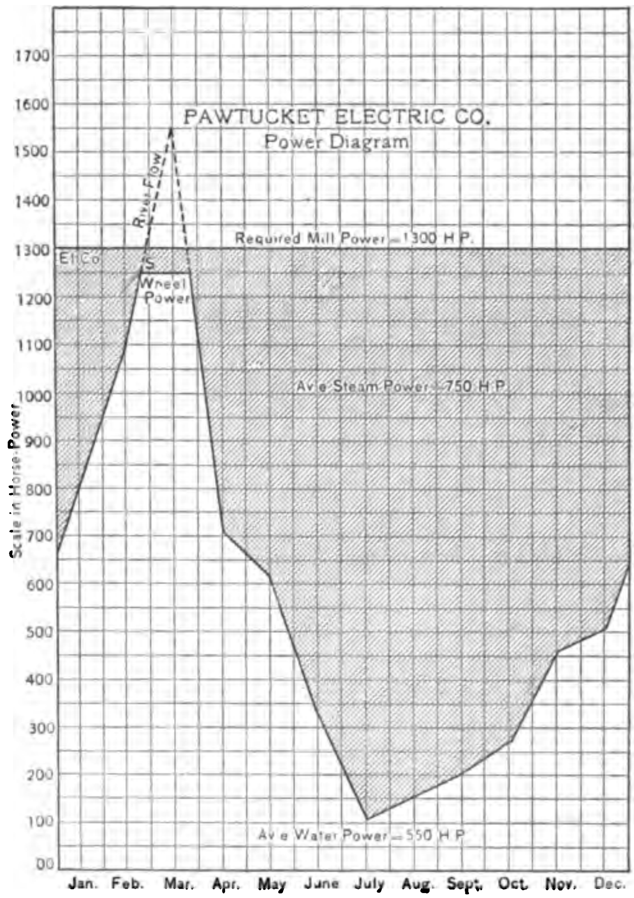


FIG. 84.

power by the rules laid down in this paper, let us assume that the minimum flow is as shown in Fig. 79. In that case water of 530 horse-power would be supplied every day in the year, and if it could be brought about that a mill required just that amount of power, the water-power would be worth $25 per horse-power (see Table I.), and the water owner would receive a revenue of $13,250 per annum. On the other hand, if the mill still required 900 horse-power, and only 530 horse-power wheel-power were available, then the calculation would stand as follows:

Required mill-power	900 Ho se-power.	
Average water-power	530 "	
Average steam-power and maximum	370 "	
Full annual cost of 900 H.-P. C. C. plant @ $22.50		$20,250
Annual interest, etc., 370 H.-P. S. C. @ $4.40	$1,628	
Annual supplies, etc., 370 H.-P. S. C. @ $7.85	2,904	
Annual coal, 370 H.-P. S. C. @ $14.00	5,180	
Total cost of 370 H.-P. steam	$9,612	9,612
Cost per H.-P.	$26.00	
Value of 530 H.-P. water		10,538
Value of 1 H.-P. water	$19.88	

12. Now let us go a step further, and under the same conditions and requirements put in a 900-horse-power wheel. Then the calculations will stand as follows:

Required mill-power	900 Horse-power.	
Average water-power	764 "	
Average steam-power	136 "	
Maximum steam-power	370 "	
Time engine runs	7½ months.	
Full annual cost of 900 H.-P. C. C. plant @ $22.50		$20,250
Annual interest, etc., 370 H.-P. S. C. @ $4.40	$1,628	
7½ mos.' supplies, etc., 370 H.-P. S. C. @ $7.85	1,815	
Annual coal 136 H.-P. S. C. @ $14.00	1,904	
Total cost of 136 H.-P. steam	$5,347—	5,347
Cost per H.-P.	$39.32	
Value of 764 H.-P. water		14,903
Value of 1 H.-P. water	$19.54	

13. Hence, we see that a mill requiring 900 horse-power with a river flow as indicated by Fig. 79, can be supplied with power by a water-power owner in one of two extreme ways. If he puts in only 530 horse-power wheels running every day in the year at this power, he will receive $10,538 net for his water, but he must spend $9,612 for steam-power in order to obtain this amount for his water.

If, on the other hand, he would put in a 900-horse-power wheel and spend $5,347 for steam, albeit it costs at the rate of nearly $40 per horse-power, he will receive nearly $15,000 per annum, or $19.54 per horse-power.

These calculations and a few others, made in precisely the same manner, are summarized in

TABLE IV.

Required Mill-Power. 1	Water Wheel Power. 2	Total net income from Water-Power. 3	Value per H.-P. per annum. 4	Cost of Auxiliary Steam Power. 5
530 H.-P.	530 H.-P.	$13,250	$25 00	......
900 H.-P.	530 H.-P.	10,538	19 88	$9,612
900 H.-P.	700 H.-P.	12,778	18 51	7,472
900 H.-P.	900 H.-P.	14,903	19 54	5,347
1,200 H.-P.	1,200 H.-P.	14,752	17 71	11,828
1,500 H.-P.	1,500 H.-P.	14,606	17 06	18,394

Monthly versus Annual Averages.

14. There is some question as to the accuracy of determining the average annual value of the water-power by the annual average, or calculating it separately for each month in the year. I have made an estimate of said values as applied to Fig. 79, by monthly estimates, and compared it with the annual average which has been used throughout these calculations. I have also introduced a corrected value of coal due to underloading of the engine, and embodied the result in Table V.

TABLE V.

Monthly estimate of the value of water-power as applied to Fig. 1.
Power required at mill ....900 Horse-power.
Cost of steam, H.-P. per annum. $22 50
Cost of coal per H.-P. per annum 9 30

Monthly H.-P. 1	Cost of Steam per H.-P. uncorrected. 2	Cost of Coal per H.-P. corrected for underload. 3	Cost of Steam per H.-P. corrected. 4	Value of Water per H.-P. based upon Col. 4. 5
160	$42 32	$17 50	$45 82	$17 47
160	42 32	17 50	45 82	17 47
160	42 32	17 50	45 82	17 47
160	42 32	17 50	45 82	17 47
160	42 32	17 50	45 82	17 47
220	34 60	16 00	36 62	17 94
350	27 00	14 00	27 00	19 67
330	27 73	14 00	27 73	19 47
300	29 11	14 50	29 61	18 95
240	32 89	15 50	34 38	18 18
160	42 32	17 50	45 82	17 47
160	42 32	17 50	45 82	17 47
210	37 30	16 38	39 67	*18 04
210	35 60	14 00		†18 52

* Annual average by monthly estimate. †Annual average by yearly estimate.

Column 1 is the average monthly steam-power.
Column 2 is the cost of this steam-power as found by preceding methods.
Column 3 is the corrected cost of coal per annum for an underloaded engine.
Column 4 is the annual cost of steam-power based upon coal value in column 3.
Column 5 is the final value of water-power based upon steam cost in column 4.

It will be seen that while the cost of steam-power (210 horse-power) based upon a yearly average is $35.60 per horse-power, it is increased to $37.30 per horse-power if made upon a monthly basis; and if also corrected for coal, becomes $39.67 per horse-power; and the value of water-power is reduced from $18.52 to $18.04, which is less than one would have supposed it to have been, and yet it is the correct way to pursue.

Successive Diversions.

15. The amount of water diverted is usually very small in proportion to the total quantity in the river.

To illustrate in detail the manner of calculating the value of the water-power per horse-power per annum when large quantities of water are taken at several intervals instead of all at one time, I have applied the calculation to a water privilege substantially like that of the Valley Falls Company, Fig. 79, where, say, 100 horse-power is taken at each interval, until it is all taken.

FIRST CASE, ORIGINAL CONDITION.

Required mill-power	900	Horse-power.
Average water-power	700	"
Average steam-power	200	"
Maximum steam-power	400	"
Time engine runs	12 months always.	

Full annual cost of 900 H.-P. C. C. @ $22.50		$20,250
Annual interest, etc., 400 H.-P. C. C. @ $6.40	$2,560	
Annual supplies, etc., 400 H.-P. C. C. @ $7.30	2,920	
Annual coal, 200 H.-P. C. C. @ $12.30	2,460	
Total cost of 200 H.-P. steam	$7,940—	7,940
Cost per H.-P. $39.70		
Value of 700 H.-P. water		12,310
Value of 1 H.-P. water $17.60		

SECOND CASE.

Required mill-power	900 Horse-power.		
Average water-power	600 "		
Average steam-power	300 "		
Maximum steam-power	500 "		
Full annual cost of 900 H.-P. as before			$20,250
Annual interest, etc., 500 H.-P. C. C. @ $6.00		$3,000	
Annual supplies, etc., 500 H.-P. C. C. @ $7.60		3,800	
Annual coal, 300 H.-P. C. C. @ $11.40		3,420	
Total cost of 300 H.-P. steam		$10,220—	10,220
Cost per H.-P.	$34.07		
Value of 600 H.-P. water			10,030
Value of 1 H.-P. water	$16.72		

THIRD CASE.

Required mill-power	900 Horse-power		
Average water-power	500 "		
Average steam-power	400 "		
Maximum steam-power	600 "		
Full annual cost of 900 H.-P. as before			$20,250
Annual interest, etc., 600 H.-P. C. C. @ $5.75		$3,450	
Annual supplies, etc., 600 H.-P. C. C. @ $7.75		4,650	
Annual coal, 400 H.-P. C. C. @ $10.50		4,200	
Total cost of 400 H.-P. steam		$12,300—	12,300
Cost per H.-P.	$30.75		
Value of 500 H.-P. water			7,950
Value of 1 H.-P. water	$15.90		

FOURTH CASE.

Required mill-power	900 Horse-power.		
Average water-power	400 "		
Average steam-power	500 "		
Maximum steam-power	750 "		
Full annual cost of 900 H.-P. as before			$20,250
Annual interest, etc., 700 H.-P. C. C. @ $5.50		$ 3,920	
Annual supplies, etc., 700 H.-P. C. C. @ $7.80		5,460	
Annual coal, 500 H.-P. C. C. @ $9.85		4,925	
Total cost of coal, 500 H.-P. steam		$14,305—	14,305
Cost per H.-P.	$28.61		
Value of 400 H.-P. water			5,945
Value of 1 H.-P. water	$14.86		

FIFTH CASE.

Required mill-power		900 Horse-power.	
Average water-power		300 "	
Average steam-power		600 "	
Maximum steam-power		800 "	
Full annual cost of 900 H.-P., as before			$20,250
Annual interest, etc., 800 H.-P. C. C. @ $5.55		$4,440	
Annual supplies, etc., 800 H.-P. C. C. @ $7.95		6,360	
Annual coal, 600 H.-P. C. C. @ $9.50		5,700	
Total cost of 600 H.-P steam		$16,500—	16,500
Cost per H.-P.,	$27.50		
Value of 300 H.-P. water			3,750
Value of 1 H.-P. water	$12.50		

SIXTH CASE.

Required mill-power		900 Horse-power.	
Average water-power		200 "	
Average steam-power		700 "	
Maximum steam-power		900 "	
Full annual cost of 900 H.-P. as before			$20,250
Annual interest, etc., 900 H.-P. C. C. @ $5.50		$4,950	
Annual supplies, etc., 900 H.-P. C. C. @ $7.70		6,930	
Annual coal, 700 H.-P. C. C. @ $9.30		6,510	
Total cost of 700 H.-P. steam		$18,390—	18,390
Cost per H.-P.	$26.27		
Value of 200 H.-P. water			1,860
Value of 1 H.-P. water	$9.30		

SEVENTH CASE.

Required mill-power		900 Horse-power.	
Average water-power		100 "	
Average steam-power		800 "	
Maximum steam power		900 "	
Full annual cost of 900 H.-P. as before			$20,250
Annual interest, etc., 900 H.-P. C. C. @ $5.50		$4,950	
Annual supplies, etc., 900 H.-P. C. C. @ $7.50		6,930	
Annual coal, 800 H.-P. C. C. @ $9.30		7,440	
Total cost of 800 H.-P. steam		$19,320—	19,320
Cost per H.-P.,	$24.10		
Value of 100 H.-P. water			930
Value of 1 H.-P. water	$9.30		

SUMMARY OF COST OF STEAM-POWER AND VALUE OF WATER-POWER AT SEVEN SUCCESSIVE DIVERSIONS, AS PER PREVIOUS CALCULATIONS. REQUIRED MILL-POWER ALWAYS 900 H.P.

TABLE VI.

Cost of Steam-power. Amount.	Per H.-P. Annual.	Total Cost.	Value of Water-power. Amount.	Per H.-P. Annual.	Total Value.
1	2	3	4	5	6
200 H.-P.	$39 70	$7,940	700 H.-P.	$17 60	$12,310
300 H.-P.	34 07	10,220	600 H.-P.	16 72	10,030
400 H.-P.	30 75	12,300	500 H.-P.	15 90	7,950
500 H.-P.	28 61	14,305	400 H.-P.	14 86	5,945
600 H.-P.	27 50	16,500	300 H.-P.	12 50	3,750
700 H.-P.	26 27	18,390	200 H.-P.	9 30	1,860
800 H.-P.	24 10	19,320	100 H.-P.	9 30	930
900 H.-P.	22 50	20,250	0 H.-P.		

16. In addition to the value of the diverted water-power, there is also a depreciated value to the remaining water-power. This is easily found by finding the value of the water-power before and after diversion, and the difference between the two, multiplied by the amount remaining, is the amount to be paid for depreciation.

Table VII. gives these amounts, as well as the direct damages for 100 horse-power diverted at seven intervals.

Annual Cost of 100 H.-P. Diverted Successively, and Depreciation of Remaining Power for Seven Periods. (See Fig. 79.) Required per Mill-power always 900 H.P. Cost thereof at $22.50 = $20,250 Annum.

TABLE VII.

Amount of Water-power.	Value of Water per H.-P.	Difference.	Cost of 100 H.-P.	Water-power Remaining.	Amount of Depreciation.	Total Cols. 4 and 6.	Cumulative Amount.
1	2	3	4	5	6	7	8
700 H.-P.	$17 60	0.88	$1,760	600 H.-P.	$528	$2,288	$2,288
600 H.-P.	16 72	0.82	1,672	500 H.-P.	410	2,082	4,370
500 H.-P.	15 90	1.04	1,590	400 H.-P.	416	2,006	6,376
400 H.-P.	14 86	2.36	1,486	300 H.-P.	708	2,194	8,570
300 H.-P.	12 50	3.20	1,250	200 H.-P.	640	18,90	10,460
200 H.-P.	9 30	0.	930	100 H.-P.		930	11,390
100 H.-P.	9 30		930			930	12,320
Total..	.....	.. .	$9,618	....	$2,702	$12,320	......

17. The accounts of the water-power owner will, therefore, stand as follows:

He receives annually from the mill owner for 900 H.-P	$20,250
Before any water is taken, he expends annually for steam-power (Table VI, Column 3)	7,940
Leaving him a net income of	$12,310

1st	When 100 H.-P. are taken @ $17.60 plus depreciation he receives from mill owner	$20,250
100 H.-P.	From city (Table VII, Column 8)	2,288
	A total income of	$22,538
	He expends for steam-power (Table VI, Column 3)	10,220
	Net income	$12,318
2nd	Second diversion @ $16.70 plus depreciation, he receives from mill owner	$20,250
100 H.-P.	From city ($2,288 + $2,082)	4,370
	A total income of	$24,620
	He expends for steam (Table VI, Column 3)	12,300
	Net income of	$12,320
3d	From mill owner	$20,250
	From city	6,376
100 H.-P.	Total income of	$26,626
	Cost of steam as above	14,305
	Net income	$12,321
4th	From mill owner	$20,250
	From city	8 570
100 H.-P.	Total income of	$28,820
	Cost of steam	16,500
	Net income	$12,320
5th	From mill owner	$20,250
	From city	10,460
100 H.-P.	Total income of	$30,710
	Cost of steam	18,390
	Net Income	$12,320
6th	From mill owner	$20,250
	From city	11,390
100 H.-P.	Total income of	$31,640
	Cost of steam	19,320
	Net Income	$12,320

7th	From mill owner	$20,250
	From city	12,320
100 H.-P.	Total income of	$32,570
	Cost of steam	12,250
	Net income	$12,320

It will be seen that the analysis proves itself correct in every instance. The water-power owner, whose income was $12,320 per annum before any diversion of water took place always receives the same figure, whether much or little, or all be taken, at intervals, or all at one time.

18. *Argument.*—It is sometimes admitted by engineers on "the other side" that my analysis for ascertaining the value of water-power may be correct, but that diverted water-power must be paid for at what it costs to take its place. Thus, in the case of No. 1 mill, the value of the water-power is $18.52, but the cost of its auxiliary steam-power is $35.60 per horse-power, and they would thus maintain that that should be the amount to be paid for diverted power. This seems very plausible, and it is a fallacy not easily seen through by engineers, attorneys, or courts; but it is a fallacy nevertheless. It is a fallacy, in the first place, because if the theory were correct, it would lead to absurd conclusions. Thus, if the entire water-power of 690 horse-power were taken (in the case of No. 1 mill) and paid for at the rate of the cost of its auxiliary steam-power, namely, $35.60, the "damages" would be $24,564, which exceeds the cost of an entire 900-horse-power steam plant.

It is fallacious, in the second place, because it makes the "damages" to an imperfect or insufficient water-power greater than is conceded to be the value of a perfect or complete one; that is, it is claimed that $35.60 per horse-power should be paid for a defective water-power when $22.50 per horse-power will pay for a perfect power.

19. It were perhaps better for a clearer understanding of this problem if the cost of furnishing the auxiliary steam-power were not reduced to its equivalent cost per horse-power at all, and simply to say that it costs the water-power owner so much money to supply the natural defects of his water-power, which expense he must go to in order to find a market for his water-power. The question of cost of steam-power is only entered into in order

to ascertain the true value of the water-power, and it is the interest of the water-power owner to make it as little as possible. As a matter of fact, for the small diverted power, it costs him only the price of coal, say $14 per horse-power per annum, while he is paid, under this analysis, $18.52 per horse-power. It is held, however, that if he is paid only for the coal consumed, he is paid nothing for his plant, etc., and that the defendant has no right to use that plant.

20. The maintenance of this auxiliary steam plant is a necessity and a burden entirely upon the shoulders of the water-power owner, in order to make his water-power worth its maximum to himself, as shown in Table IV., and that maximum value of water-power the defendant is willing to pay.

Two causes are at work which make this auxiliary steam-power disproportionately expensive: First, the natural fluctuation of the river flow; and, second, its insufficiency for the uses of the mill. Neither of these causes are the fault of the defendant, except in the latter case, by the amount of diversion. It is not the fault of the defendant that the auxiliary power costs what it does, and he should, therefore, not be made to pay for it. When he has paid the "market" or "commercial" value of the water-power, plus the damages inflicted upon the balance of remaining power, he has met the requirements of equity.

21. *En passant* I may allude to the favorite illustration of eminent counsel, that if a man brings into the city horses which he is selling for $100 apiece, and the city takes for its own use one or more of his horses, the city must pay $100 for the horses taken, and not $50 or so, or whatever they may cost him. I agree to the correctness of the claim of the plaintiff. On the other hand, the plaintiff attempts to establish the "market" value of steam-power by asking a tenant at some city factory what he pays for power. The case of a tenant at a distance from the source of power, and in small amounts, is not an analogous case with the one with water-power at a mill. Here the entire water-power is absorbed by one purchaser, and in order to give the entire water-power its maximum "commercial" value, an incidental expense is necessary, with which the defendant really has no concern.

22. *Theorem* 3 expresses the true basis upon which "damages" should be paid. Under the analysis here laid down the water-power owner is not injured one dollar whether much or little water be taken, for he is assured precisely the same annual in-

come he received before the city trespassed upon his rights as after.

In the suit referred to, however, the amount of power diverted is so small compared with the river flow or total mill power that I neglected to compute this item.

I believe that a careful study of this paper, however crudely the subject-matter may have been set forth by me, will convince the reader of the correctness of the theorems announced, and I shall be satisfied to leave hereafter to more graceful pens the task of presenting the subject so that no court will ever go astray again on this abstruse economic-engineering problem.

DISCUSSION.

Mr. George I. Rockwood.—According to law, when a piece of property has been damaged and its value thereby reduced or destroyed, the extent of the damage in money is to be estimated by finding the difference between the fair market value of the property before it received the injury and that value afterwards. This difference represents the compensation to which the owner is entitled.

I am told there is no exception to this rule, and it is obviously just; but in the case of suits brought for the recovery of damages occasioned by the diversion of some or all of the water from a water power privilege, it has been found very difficult to apply tho rule with satisfaction to both parties, and some definite light upon the subject is badly needed. I cannot see wherein Mr. Nagle's paper provides much illumination on the general question. In so far as his ideas are correct, I think they are not novel, for he only applies in particular instances some general principles first enunciated years ago by Mr. Charles T. Main.

As a result of what study I myself have been able to give to these general principles, considered in view of the legal rule of damage just stated, I believe it is the relation of the engineering features to the legal method of appraisal which causes all the trouble. The lawyers and tho engineers do not see eye to eye respecting what the legal issues really are.

To apply the legal rule of damage to any given case it is necessary, as a preliminary to all testimony, to define two of its main points: (1) Just exactly what the property is which the diversion of the water damages. (2) Just where the market for its sale lies.

With regard to 1, it may be said that it has been held that the measure of damages for the diversion of a stream from a manufactory was the diminished rental value of the works during the period of diversion. In this case the lawyer says that the particular property damaged is not the water privilege as such, but the mill property. The value of every part of that mill property—land, buildings, machinery and tenements—has been injured by the diversion of the water from the mill-dam. If the water could be counted upon to continue to flow to that dam in the natural quantity, the value of all that mill property was one sum. If the water has been diverted, all this property sinks in value. The difference between what it was worth with a water supply at the dam and what it is worth without that supply, is the damage suffered by its owners by the diversion. In other words, the lawyer here regarded the right to use the full natural flow of the stream as a characteristic of that mill property—an "easement" or incorporeal right appurtenant to the mill real estate. His view contemplates the damage done to the owners in view of *all* of their property, which was originally located at the stream because the flowing water was there; and it contemplates the damage done by the loss of every use to which that water could have been put in connection with the manufacturing carried on in that mill. This is evidently a very broad view of the damage done that mill property by the diversion. Moreover, it is the traditional way to appraise such damages, and it is thought by some lawyers to be the only possible way.

It has also been held, however, in another case, that the measure of damages was the actual value of the use of the water during the time it was diverted. This measure of damages seems to be much broader than the other in that while it includes the loss suffered by a mill owner for the uses to which he could or did put that water in his own mill—and hence measures, at least, the reduction in the fair market value of his mill real estate by the diversion—it also contemplates the loss in value of the use of the falling water by any other user than himself. In this view of the matter a riparian privilege is a piece of real estate itself, as much so as the land or its improvements. If there is no possible user, situated within miles of the privilege, other than the mill to which it is adjacent, then its fair market value is quite plainly the value which the owner of that mill could reasonably set upon it; and the "easement" theory would lead to the same conclusion.

But very often, nowadays, the conditions are much more complicated, and the "easement" theory leads to very awkward situations. For example, suppose a large cotton mill to be on one bank of a waterfall and a much smaller mill, manufacturing woolens, on the opposite bank. The stream is variable, has very small storage capacity, and is used fully and equally at each mill for power, steam, and washing the goods in process. The balance of power each mill requires is made up by engines. There are other mills in the neighborhood which are run by steam-power and use city water for manufacturing purposes.

An electric railroad passes within a stone's throw of the mill-dam, and is run by a steam-power plant. If water is diverted here and the case is tried on the lines of the easement theory, the result would be that no account of the propinquity of that railroad would be taken at all, and that one of those mill owners would get bigger damages than the other, although both own equal parts of the privilege, and each makes a full use of his part. But if the water privilege is considered to be property and the particular piece of real estate affected, then experts on the value of each use of the water can testify as to the damages resulting from the loss of that one use; and the sum of these damages represents the loss in the fair market value of the privilege, and should be the compensation. The mills might desire to use the water in their boilers and to pass it through their washing machines. But as they only run five and one-half days of ten hours each per week and not at all on holidays, whereas the electric street railway runs every day in the year, sixteen hours a day, very likely the power part of the privilege would soon be sold to run the railroad. In the old days, when the doctrine that water power was an easement of a particular piece of land grew up, such a market for that power was unthinkable. To-day the electric railway people would not give a cent more for the use of that power because of the presence of the tenements and the mills and the machinery. All they want is the power. Whereas, originally that privilege had no value apart from the mills, and they could not run without the power of the flowing water, and would have had to stop and their machinery to be dispersed and the fixed improvements left to decay if the water had been diverted, now it is very different. Civilization has developed about them. An excellent quality of mill population has appeared. The town has been made a desirable place to live in. The cost of the competing power of steam has been very much reduced. To-day it is not improbable that if that dam were washed away before any diversion of the water, it would not be rebuilt; or the right to rebuild it and to use the power would be sold to the railway. A water privilege is no longer the pivotal element in business it once was. It is worth just what can be got out of it in competition with manufactured power and city water supplies in favored regions, and no more.

Suppose the railway bought the privilege and a strip of land ten feet wide down to the wheel-house from the highway. Is that privilege an easement to that strip of land? That seems to be putting the cart before the horse. The land cannot be further improved. It has no value except as a right of way to the dam. Is the privilege an easement to the whole railway? That would be absurd, because the privilege was there before the railway, and is independent of it. The simplest way is to consider that privilege as a piece of real estate by itself and value it accordingly for any fair market value it had before and again after the diversion. If used for power, then an engineer who knows how much and how constant the power is can state with accuracy just how valuablo this use of the water is, in view of the market for the sale of such use. If it is, or may with reasonable likelihood, be used for any other purpose at the same time that it is used for power, such as for washing textile goods, or for boiler feed-water, or for fire protection, or for irrigation, or watering stock, then its value is found by adding the several values of these various uses as determined by the testimony of those who are experts in appraising such uses. But it is rarely necessary to make an appraisal of all the land and mill property of which the owner of a water privilege happens to be possessed, both before the diversion and afterwards, in order to find out what was the fair market value of the privilege which has been destroyed. This obviously cannot be done in the case of an undeveloped privilege, there being no land improvements whatever to appraise.

Mr. Nagle says nothing about how to value undeveloped water power; nor how to appraise a developed water power for any other than the specific purpose for which it happens to be used at the time of diversion. His method, if I understand what it is, is not uncommon. It starts with the assumption that the measure of its value is the capitalized net saving due to its use in a mill requiring a stated power to drive it, and proceeds to find out what that saving was beforo the diversion, and what it is after the diversion. The difference represents the net loss of income, and this sum, capitalized at a fair rate per cent., represents the damages due to the loss of power.

Thus, in paragraph 15 he calculates the value of the saving before the diversion as $12,310. This is his "First Case, Original Condition." Next, he calculates the value of the saving after the diversion of 100-horse-power as $10,030. The difference between $12,310 and $10,030, or $2,280, may be found in Table VII., first sum in column 7, which column purports to be the "direct" damages for 100-horse-power diverted. But Mr. Nagle does not seem to realize that this is what he is doing, for Theorem 3 says: "The damages to be paid annually for a given amount of diverted water power is the value of the diverted water power as found by Theorem 2, plus the depreciation in the value of the remaining water power."

The water power which was diverted has the value per horse-power found by the rule Theorem 2 only when the value of the water power as a whole is considered. But the value of the diverted power per horse-power, when estimated in the light of the depreciated value of the balance of the power, is worth more. It is worth as much more as the balance of the power is depreciated by its loss. This is what Theorem 3 says. Then why make the calculation at all as to what it is worth considered as a going part of the whole? It is such tables and obscure statements as these which bring confusion instead of conviction to the mind of the Court.

Theorem 1 leaves one to infer that a power of invariable amount is worth whatever it would cost to do the same work by steam power. Of course this depends entirely upon the situation. If fuel is high in cost, then in all probability the location is remote from market, and the value of the power is reduced by the extra cost of freight of the finished goods, or else by the extra cost of transforming the water power into electric power, and of transmitting it to the point where it is to be used; and this cost of the competing steam power must be found, not at the waterfall, but at the place where the power is to be used.

I believe the theory of estimating the damages caused to a water power privilege by the diversion of a part or all of the water from the dam is substantially correct, as conveyed by Mr. Nagle in this paper; but it does not cover the whole ground by any means, and it is hardly new in any particular. In applying this theory it must be remembered that the fair market value of the privilege, so far as the use of the water for power is concerned, depends upon the greatest value it could reasonably be expected to have at the time of diversion to any one or all of its possible buyers. This, as Mr. Nagle shows, is because the competing steam power costs less and less per horse-power as the total steady power required increases.

The amount of power which a turbine develops, or the amount of water which passes through it, may be recorded minute by minute, hour by hour, and day by day, by the use of an appliance invented and protected by Prof. C. M. Allen, of Worcester, the broad idea being a development from a suggestion which I made. It is a device for recording the discharge of a turbine wheel using the turbine itself as a water metre. In view of the fact that Professor Allen has consented to give a detailed description of the principles of his device as a separate paper, I will not enlarge upon its construction and action, other than to say that it has been applied for about two years, and that the result of the experience had shows that the problem has been solved satisfactorily, both from the scientific and practical standpoint. The special field of usefulness for this machine is where power is sold on a basis of measurement of head and gate opening twice a day throughout the year.

Mr. H. de B. Parsons (contributed after the Meeting).—The commercial value of any water power, whether large or small, is difficult to determine in a manner which will prove satisfactory to both the seller and the purchaser. It is fair to assume that the seller will value his power privilege as high as possible, and will advance reasons for so arriving at his estimate which will have to be considered.

The purchaser (either a buyer of the privileges or a party liable for damages for diversion) may be willing to pay a fair value, but not a value such as claimed by the seller. If the parties could agree on a sum to be paid in every case, there would be no need of any "valuation" to be determined by testimony, argument, or calculation. Unfortunately, the valuation of a water right is seldom so easily settled, and the problem has been presented in so many cases as to prove it to be difficult of easy solution.

The value of a water right is divisible into two parts, viz.:

(*a*) Value of water privilege, *per se*.

(*b*) Value of water power, as utilized.

The first part represents what could be classed as "speculative" value; that is, the ownership is worth something for development, and the question is "how much?" This speculative value must be peculiar to each individual case, and depends on geographic location and local needs. Thus, a vast power situated somewhere in a distant location, far from civilization, is worth, at the moment, less than a small power near a large manufacturing centre. Again, a power near a manufacturing centre where fuel is cheap is worth less than one near an equally advantageous centre where fuel is scarce.

The second part has a value varying with the proportion utilized. Thus, if all the power is developed, the total "commercial" value of the water rights would be found under this head. If only part were developed, then the value would be part under both heads (*a*) and (*b*). The question again arises, "how much should be determined under (*a*) and how much under (*b*)?" According to the Author, all value under (*a*) has been neglected, and only such value as may be attributed under (*b*) has been considered.

Furthermore, the assumption has apparently been made that the privilege has been fully developed. This is but one case out of many which may be found in practice.

A privilege may be developed for a specific factory purpose, using all the water of the stream, but for an addition or for another factory that power may not be sufficient. An increase in the height of dam is often a condition which may be effected without flooding other rights. The value should include something for such a possible increase of development.

The Author's general scheme of obtaining an estimate of value is correct as far as it goes, but is neither comprehensive nor broad enough to include all conditions, and, therefore, is not final. Water privileges are not alike. All have peculiar conditions which cannot be neglected or generalized. There are numerous difficulties involved, such as the amount of power available, the completeness of the development, the standard for comparison in cost of a steam horse power per annum, etc., which make the problem one for serious consideration, and which apppear to prevent generalization, owing to the variable character of the items composing the same.

*Mr. Nagle.**—To fairly answer Mr. Rockwood's criticisms would be to take up the arguments presented by the attorneys for the plaintiff, which I can hardly be expected to do. But, fundamentally, their erroneous views arise from the lack of a proper division of the complicated problem into its simple elements. So far as a water power affects land, mill, or tenement values, the word steam power may just as well be substituted with equal force to the argument. Any industry gives a certain value to surrounding properties, regardless of the particular kind of power it uses. The destruction of any portion of the power operating said industry would, of course, affect the values of all properties surrounding it; but to attribute any different effect from the destruction of a portion of a water power than from the destruction of an equal portion of a steam power, seems to me to be extremely irrational. Hence, any arguments which tend to give as great, or even greater, value to a water power, under usual conditions, than its equivalent steam power, is full of sophistry. There is only one way to obtain "damages" in excess of the value of the water power taken, and that would be a purely hypothetical case, where the water power was complete and perfect every day in the year to supply the needs of a mill; or where sufficient water power was available to supply the power of the mill, without auxiliary steam power before any water was diverted or taken, but requiring the installment of a steam plant to make good the amount diverted. In such case, worked out strictly in accordance with the rules laid down, it will be found that the "damages" would amount to the cost of operating this newly-installed steam plant and, of course, exceed the value of the water power. But, of course, no cases were involved in the suit.

It seemed to me that Mr. Rockwood failed to grasp the important part of the paper, pointing out the necessity of separating in the analysis the mill owner from the water power owner as having two antagonistic interests, that of buyer and seller. I thought it important to have demonstrated that the high cost of the variable steam power of a mill diminished the value of its

* Author's closure, under the Rules.

water power. Thus, in the case of No. 5 Samoset Mill, the variable steam power may cost $40.00 per horse-power per annum, while its variable water power was worth only $17.31. Hitherto it had been contended that "damages" for diverted power should be paid for at the rate of this $40.00, the cost of steam power, but I have demonstrated that it should be paid for at the rate of the $17.31, the value of the water power.

We need no longer to contend against the claim of the plaintiff that his variable steam power costs him $40.00, $50.00, or $60.00 per horse-power per annum, knowing that the fact proves the smaller value of his variable water power, and for the loss of which only we pay "damages."

Mr. Rockwood thinks I confuse, rather than make clear, the way the "total damages" are given in column 7 of Table VII. In column 4 is given the direct damages for taking 100-horse-power, at $1,760 ; under Theorem 2, column 6 gives the amount of depreciation ($528) for the remaining water power; under Theorem 3, column 7 gives the sum of these two. It is true that a simple statement of the value of the water power before and after diversion of any part of it would be sufficient, but to my mind it seemed more satisfactory to point out the steps which led to the result.

I have no disposition to appropriate Mr. Main's studies as my own. I had not read Mr. Main's paper until Mr. Rockwood called my attention to it, and I do not now find in it what I have set forth in my paper; but if we have reached the same conclusions, as Mr. Rockwood says we have, I am sure that Mr. Main and myself will be equally pleased.

Mr. Parsons says that "the general scheme of obtaining an estimate of value is correct as far as it goes, but is neither comprehensive nor broad enough to include all conditions, and, therefore, is not final, etc." I accept this criticism as being just, but must explain that I naturally limited the scope to the conditions prevailing in the case before the Court. On the other hand, I must add, that if the "scheme is correct as far as it goes," it not only goes far enough for the case in hand, but can be readily adapted to other special cases.

No. 968.*

TOPICAL DISCUSSIONS AND NOTES OF EXPERIENCE.

No. 147.

Smoke Consumption.

Prof. F. R. Hutton.—At a recent visit to an important producing plant just outside of Syracuse, attention was directed to the

Fig. 85.

appearance against the sky of two columns of products of combustion, which are presented in the photograph. The stacks are of about equal height; the brick one takes the products of combustion from 3,500 horse-power Babcock and Wilcox boilers, which are fired by hand. The steel stack to the right of the brick stack is discharging the smoke from 3,600 horse-power of the same type of boilers, operated with mechanical stoking. The

* Presented at the New York meeting (December, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions.*

coal used is the ordinary run of mine from the Clearfield district of the usual soft-coal type, and the rates of combustion, as far as have been observed, average 18 pounds per square foot grate per hour for the hand-fired battery, and about the same for the stoker. It is, of course, difficult in a photograph to secure the profound impression which is made upon the eye even with a background of a gray sky.

It happens quite often that the mechanically-fired boilers show less volume of smoke than at the time chosen in the photograph, but these represent average conditions as nearly as can be represented. The distant stack, towards the left of the photograph, represents the discharge from a boiler house of the same size and arrangement as the hand-fired one above described.

Mr. A. Bement.—There is in use in Chicago, under boilers, every type of furnace from the plain hand-fired grate to chain grate stokers and coal dust firing apparatus. An example of each may be selected which makes practically no smoke at all. On the other hand every one of these types may be observed in other cases to be very bad smokers.

A liberal air supply has been quite generally assumed to be required to assure the oxidation of the carbon, yet the gas analysis may show air in excess to the extent of two or three hundred per cent., with very much smoke, an abundance of oxygen being present in the furnace but not coming in contact with all of the carbon of the gases during the period that the temperature is high enough for union. An ordinary tallow candle has a flame about one inch long with the gas burning on the outside of its mass; if the candle should be much larger, with a wick to correspond, then the mass of gas would be larger in proportion, and consequently the flame must be larger because the mass can burn on the surface only. With a small piece of coal there would be a short flame; a large piece, however, would give off a large mass of gas, and, consequently, there would be a long flame, which would require so much time in burning that it would reach to the heating surface and be cooled below the temperature of union resulting in smoke.

The cause of smoke is a failure of an intimate mixture of gas and air during the brief period of sufficient temperature. If it were possible to thoroughly stir the gas and air together in the furnace so that there would be a complete mixture, the result would be, with a sufficient air supply, that all of the carbon would be oxidized to carbon dioxide; with a less air supply the tendency would be to produce carbon monoxide, each a colorless gas, unaccompanied by flame. It is in an effort to promote such mixture that steam jets are employed, likewise arrangement of brick work tending to influence the flow of the gases, and stir them together.

Best results will be had in preventing smoke when the efforts are directed especially to the effecting of a thorough mixture, which will require, with a furnace directly exposed to the boiler, that it be obtained as quickly as possible, while with a furnace covered with an arch there is more time.

Generally best results with hand firing are had with small sized coal, fed uniformly over the surface of the fuel bed in a thin layer, and the coaling being as near continuous as possible. This method, with a clean grate, has been quite successful. An accumulation of clinker is harmful because it obstructs the air supply to the fuel above it. This is similar to the action of mechanical stokers and implies that the hand method be made to conform to the performance of the machine as far as possible. With mechanical stokers, the coal is usually fed to one end of the grate and the ash discharged at the other, but with hand firing the supply of fuel is at the top of the fire, and it would be desirable to discharge the ash from the bottom. This has been quite satisfactorily accomplished by means of a shaking grate continuously kept in motion. Its action, together with the occasional prompt removal of a small clinker, has insured a clean fire and made the occasional cleaning of the fire unnecessary.

A uniform feed of the combustible of all else is most important, and in this connection Fig. 87 is of interest. This furnace is a gravity stoker feeding from the front and provided with vertically inclined fire bars. The fuel did not feed down the incline in a satisfactory manner, and as the machine would itself operate, the gas analysis showed about 6 or 7 per cent. CO_2, and 12 or 13 per cent. O; consequently the efficiency and capacity were both low, but there was no smoke. That the capacity should be greater, the practice of forcing the coal down the grate by means of a poker through the corner doors was adopted; this resulted in making much smoke. When the work of correcting the trouble was undertaken, the econometer in the plant was moved to this furnace and connected. The readings shown by the curves in the diagram, Fig. 87, were taken every minute, one of a period of two hours and twenty-six minutes; the other, two hours; both covered an

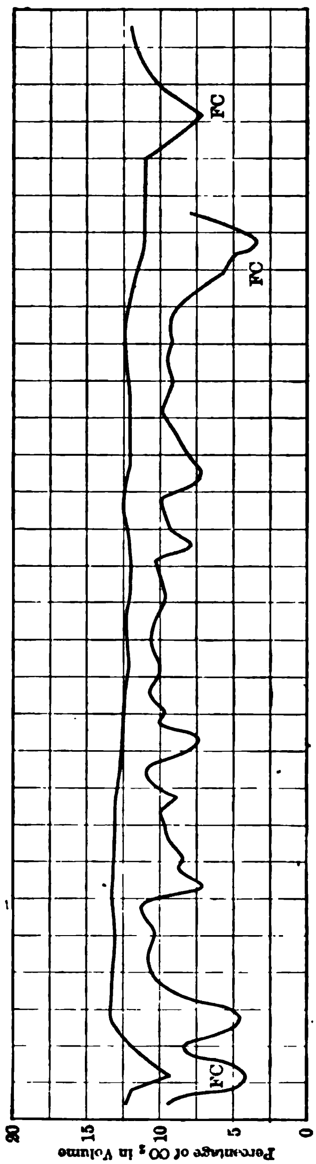


FIG. 87.

interval which included two cleanings of the fire, at which time the lower portion of the grate was opened. These cleanings are designated as *FC*. It had been the assumption that after the fire was cleaned, an immediate large supply of coal was required. For this reason coal was poked down, resulting in the large drop in CO_2 as shown in the lower curve. All of the drops in this curve were caused by poking down the coal with the exception of those at the time of cleaning the fire, and were accompanied by escaping hydrocarbons, incomplete combustion and smoke. The upper curve shows the improved practice secured by more careful manipulation, the feed of the coal down the grate being helped by means of a thin slice bar through the lower portion, so used as to help the ash in its descent. This resulted in an entirely

FIG. 88.

smokeless combustion and a larger capacity than had been obtained before. The plant has between 70,000 and 80,000 square feet of boiler heating surface, served by 10 gravity feed stokers as mentioned, 12 chain grate stokers, two down draft furnaces and three hand fires with shaking grates. Of these the gravity feed stokers, the down draft furnaces and eight of the chain grates were served by the large chimney shown in Fig. 88; the others by another chimney not shown. The three hand fires of 52 square feet of grate each were fired by two men who made much smoke. The remedy applied to these three units consisted in reducing the grates to 47 square feet, and putting a man to each fire. The result, with the method of firing as outlined above, was very satisfactory and later a fire brick arch was sprung over each fire and steam jets placed in front with the object of making the work easier for the men.

The two down draft furnaces had been fired by one man. This was changed by putting a man to each furnace and adopting the following method of working the fires. A rather thick bed of coal was maintained on the upper grate, which was frequently and carefully sliced, in a manner to ensure that the hot coke in the bottom of the bed would drop through to the lower grate, and that the green coal would not be disturbed enough to drop down. Immediately after each slicing the fire on the bottom grate was leveled with a rake. The lower fire was kept clean and it burned about as much fuel as the upper one. One of these furnaces of about 100 square feet in both grates would burn more coal with this active condition than one man could furnish if given full air supply; therefore, the ash pit doors were kept partly closed to keep down the capacity. With this method the CO_2 would average as high as 14 with no CO and there was almost no sign of smoke.

The gases from the chain grate fires went directly among the tubes of the boiler and there was always some smoke, not such an amount, however, as would have justified the large expense required to make the changes in the apparatus that would have ensured their correction.

The condition of the chimney in the photograph shows the result of the improved methods, the smoke issuing being about the average and almost all of it from the chain grates. This example is interesting inasmuch as it was a most serious case of smoke nuisance, and the three types of furnaces that gave the trouble were corrected without any changes in the apparatus.

In an experiment to determine the relative amount of smoke made by a down draft furnace with the then prevailing practice, as compared to that outlined above, a metal strip was suspended in the flue for a required interval; the accumulation of carbon was then scraped off and weighed. During the evaporation of 1,000 cubic feet of water with the practice that prevailed the weight of the carbons was 63 milligrams. With the improved method during the evaporation of 1,054 cubic feet, the accumulation was 3 milligrams.

Referring to Fig. 89, the four chimneys of one of the Chicago Edison Company's stations will be seen, two appearing on each side of the passing schooner. These are examples of what may be accomplished with a bituminous coal as a fuel. The furnaces are

FIG. 89.

equipped with chain grates, and have a long tile roof extending to the back of the boiler.

Arches, "Dutch ovens," etc., are often considered as accomplishing much in the way of preventing smoke. It will be in-

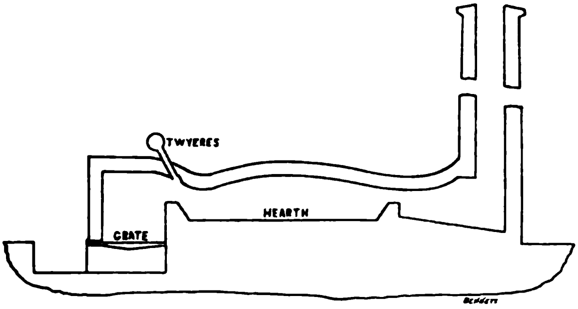


FIG. 90.

teresting to view the matter from the standpoint of a reverberatory furnace as indicated by Fig. 90. The length from bridge-wall to chimney in this case is about 21 feet, and the height of the chimney 45 feet. As the chimney lining is at least red hot for a considerable distance, it is a case most favorable for high temperature, with opportunity for the gases to mix together unobtainable in the case of a boiler furnace, strong air jets from the twyers are also an assistance. Such furnace, when fired uniformly at frequent intervals, will show no smoke at all, but a heavy coaling will produce dense smoke.

The best scheme for a smokeless furnace appears to be the combination of a mechanical stoker, ensuring a uniform feed of the coal and a large mixing chamber. Steam and air jets, arches, mixing and combustion chambers, all have advantages, but not enough to overcome the effects of irregular and heavy coalings. Probably the two cases illustrated in Figs. 88 and 89 show the value of the hot chamber. The stoker in each case is of the same make; with each the mixture of combustible and air starts right at the fire, but with one it is not finished on account of the presence of the cooler boiler, while with the other it is perfected in the mixing chamber.

Mr. E. P. Bates.—I will just say a word. Something perhaps that every gentleman here may be more familiar with than I am myself. But to illustrate, in my early practice I was in St. Louis fitting up some large buildings with steam apparatus, and every one knows how smoky St. Louis was a few years ago, but on a later visit there I was talking with the engineer of a building where they were operating my apparatus, and we were commenting on the difference in the appearance of the city. He, the engineer, said, " The city has passed an ordinance which prohibits the escape of smoke under penalty of heavy fines." It was a prohibitory ordinance, and he said, " Come up on top of the building." We took an elevator and went up on top of the building—the first 10-story building ever built in St. Louis—and observed the tops of the chimney nearby. The engineer said, " There is a building nearby that consumes so many tons of coal per month to run its elevator, heat and pump water. And when this ordinance was passed the owner went to the engineer and said, 'I will give you all the saving you will effect in fuel if you will prevent the escape of black smoke from your stack.' " The engineer took it up and began a system of firing different from the careless firing which they had previously been practicing, and which nearly every engineer permitted. The custom was in using the Illinois coal which our friend speaks of, to open the door and cover nearly the entire surface of the fire thickly with very poor coal. Of course the temperature of the furnace dropped down to a very low point and the consequence was that the black smoke would pour out for several minutes at least. But in the new system they fire the coal on the front of the furnaces; say about 16 inches of the front of the grate was fired with fresh coal. The remainder of the fire was left incandescent. The coal fired on the front of the grate became coked and in a few moments was spread by a hoe over the fire. Another instalment of fresh coal was put on the front of the grate, and in that way they were enabled to fire with very much less fuel and had no black smoke issuing from the stack. There was color, though, from the top of the stack, very visible, but it was gray and not black, and in the building to which I refer the engineer increased his pay some $14 a month by the saving in fuel.

Mr. Gus C. Henning.—I would like simply to explain what I have seen in Vienna, where the Central Electric station is placed immediately opposite the Archduke Albrecht's palace, and the condition, I believe, on which 16,000 horse-power was allowed to be put there on the banks of the Danube, was that no smoke shall ever issue from the stacks of any one of 64,250 Babcock & Wilcox boilers, for the period of 15 minutes. If the smoke issued ever so little they were fined heavily, so much a minute for the time the smoke issued. I went there and examined those boilers, one row of which was completed and had been in operation for several weeks, burning Austrian coal, being the poorest and dirtiest of coals (much worse than the Illinois coal), I was shown how that apparatus was operating. They simply admitted a little air and steam through a certain apparatus on the door and within the furnace, into the furnace, and when the door was closed it made the apparatus operative. Shutting off the apparatus smoke issued from the stack within two minutes. There were two stacks, one for each set of boilers, and I think I am not mistaken in saying they were 32,250 horse-power boilers in one row on each side of the centre. Within 15 seconds the inspector blew the whistle to notify them that the chimney was smoking. There was simply a trace of smoke coming out. The foreman came and raised an awful row among the Hungarian firemen. He did not know we were there experimenting with the boilers. Within another half minute that smoke had ceased because they simply closed the door and allowed the apparatus to operate. It is an automatic apparatus which operates through pneumatic pressure in a chamber on the furnace door and the quantity of steam admitted through a peculiar nozzle right above the furnace door produced perfect combustion so that smoke was not produced. In the City Hall at Vienna they have exactly the same apparatus, and in the famous Opera House and Court Theatre in Vienna as well. Never does the slightest trace of smoke issue from any of these buildings. We cannot here realize what filthy coal is used there. They also use this apparatus on locomotive engines, and thus stopped the production of smoke there to a great extent. I must say one thing—they fire very frequently. Because with this poor coal this is one of the essentials. They fire almost by the clock, feeding regular numbers of shovelfuls. Otherwise the thing is automatic. There is no difficulty at all there in preventing smoke production.

Mr. Bates.—I would like to have Mr. Henning tell us perhaps a little more explicitly what he means when he says there is no smoke. Is there any color at all of the gases that escape from the top of the chimney?

Mr. Henning.—There is absolutely no color.

Mr. Bates.—Nothing to see?

Mr. Henning.—Absolutely nothing until they open the door to fire, when for an instant, you will see a little color—not smoke, a yellow coloration, the beginning of the smoke and as they have to throw in so many shovels of coal, two men do it, one opens the door and the other throws in the coal. There is no smoke produced. Before the cold air has a chance to prevent complete combustion, the furnace is again closed. It has been in use now since 1895 in the City Hall and for several years before that in other places; but its latest development at the electric station was absolutely perfect. It is the Langer system of smoke prevention.

Mr. H. de B. Parsons.—(Contributed after the meeting.) In order that a fuel may be burned so as to produce little or no smoke, it is necessary that three requisites be fulfilled:

1. An excess of air must pass through the furnace;
2. A high temperature must be present; and
3. The constituent particles of the fuel must be thoroughly mixed with the incoming oxygen before the temperature has been reduced below that necessary for chemical union.

The object sought should be smoke prevention, and not smoke consumption.

The loss of heat, due to the lack of combustion of such constituents as form smoke, is small, probably not exceeding 2 per cent.

In practice, therefore, there is little direct economy gained by a "smokeless" fire. On the other hand, smoke generation is most frequently a sign of imperfect combustion, and an evidence that other losses than simply smoke generation are taking place. An effort, then, to prevent smoke will result in economy, due to changed conditions in the furnace. It is to this cause, and not to "smoke consumption," that the so-called smoke consumers may, and sometimes do, show improved results.

The steam boiler is purposely designed to absorb the heat of the fire, and is intended to let only so much escape as may be necessary for draft creation. This condition cools the products of combustion often below that necessary for the union of oxygen with carbon or hydrogen. Unless, therefore, the union has taken place before the particles are properly mixed and drawn against the cooling surfaces, under the swift action of a fierce draft, imperfect combustion will result.

As the greatest heat is generated by perfect combustion, the fuel should be completely burned *before* the products pass to the boiler surfaces. The plans should so arrange the furnace and the boiler, that each may meet its own conditions, which are contrary and opposed to one another.

The simplest arrangement would be to separate the furnace in a fire-bricked chamber, large enough to effect complete union, and then pass the hot products to the boiler. Whenever this plan has been properly carried out, the result has always been satisfactory. It has incidental advantages, such as the prevention of cold air striking the hot boiler plates during periods of firing, as well as fuel economy and smoke prevention.

No. 148.

Has any term ever been suggested to discriminate between the elastic resistance offered by a body to a force tending to change its shape and that offered by the same body to a force tending to change its volume? How much of the latter kind of elasticity has India rubber?

Mr. F. J. Miller.—In regard to Topical Question No. 148, I assume that what is meant by the term "elastic resistance," is resistance to compression or change of form or volume within the elastic limit of the substance. I do not know whether we have a term which discriminates between that kind of elasticity which permits a body to change its form and return to it again, and that which permits it to change its bulk and return to it again, but that we should recognize the difference between the two things in practice was strongly impressed upon my mind by some experience I had in my earlier days of working with machinery, when, having repair work to do in a large manufacturing establishment, I noticed that the steel neck or gudgeon of a feed roller in a woodworking machine was very frequently broken off, which necessitated boring out the inserted part and fitting a new pin. This breakage occurred so often that I finally concluded to make a further investigation, and then found that the roller was pressed to the lumber by a spring, which spring was a piece of rubber, similar to that used for car springs; it was cylindrical in shape and inclosed in a solid iron shell, within which the rubber fitted closely, preventing its lateral expansion when compressed endwise.

Prevented thus from expanding laterally, it was in reality about as solid and unyielding as a block of oak wood would have been, and was therefore really no spring at all; the natural result was that a board a little thicker than the usual one would invariably break off the neck of the roll. This rubber was replaced by a helical wire spring, and there was then no further trouble.

Now it is evident that if there had been a close-fitting piston in this iron shell, with air confined above it, this air, by reason of its elasticity, would have allowed the piston to rise upon occasion, and the roll with it, thereby preventing the breakage. In other words, the elasticity possessed by air allows it to change its volume, while that possessed by rubber seems to allow it to change its form only; or, at least it seems to possess very little of what might be called elastic compressibility.

Inventing a term to distinguish between these different kinds of elasticity might be the appropriate work of a philologist rather than of an engineer, but we commonly refer to both rubber and air as being highly elastic. That there is an important difference in the way they manifest their elasticity seems evident, and it might tend toward greater clearness in our treatment of mechanical subjects if we had a term or terms which would distinguish between the two manifestations or properties.

The mathematicians have gone into the questions of elasticity and elastic resistance very thoroughly, and as I remember it from my school days it requires for complete discussion partial differential equations and other mathematical expressions that would be worse than any that have ever been presented to the Society.

Briefly, however, I may note that two kinds of elasticity are frequently referred to. First, the elasticity of volume or the change of volume for a body subjected to uniform pressure over the whole surface. This is the only kind of elasticity possessed by liquids or gases. India rubber is in respect to this kind of elasticity in much the same class as steel or wood or water.

The other form of elasticity is also known as rigidity and is the resistance to shearing. If we consider an elementary cube or square of a body that is to be subjected to shear, then the sides of this cube or square will under shear be shifted sideways so that the square becomes a rhombus or parallelogram, and the amount of this shifting is used as a measure of the elasticity.

What is commonly referred to as elasticity is, of course, a composite of both expansion and contraction. Thus when a piece of India rubber is pulled it expands lengthways and contracts sideways, or if it is compressed sideways it will expand lengthways. The resulting stress acting on any small portion of the piece is quite complicated and is apt to be in the nature of a shear. This is shown by the familiar fact that when test pieces are broken in compression the line of fracture is apt to be at 45 degrees to the axis, while when broken in tension the cup-like fracture that often occurs shows that the force acting at any particular point of the test piece is not necessarily simple tension.

The term " Young's modulus " is frequently used to refer to the elasticity of a body in a longitudinal direction that is free to expand or contract laterally. This would be the kind of elasticity possessed by India rubber, or by a helical spring.

Another point in which scientific and vulgar usage differ is in respect to the measure of elasticity. The measure of elasticity is, in most treatises on the subject, taken as the force required to produce a given change of volume or a given extension, so that water or steel, which require a large force, have a high coefficient of elasticity, while India rubber or air are very easily compressed, and possess a small coefficient of elasticity. In other words, a body with a small coefficient of elasticity is vulgarly referred to as being *very* elastic while if the coefficient is *large* the common expression would be that the body was inelastic.

If a body is homogeneous and has the same qualities in all directions, then it will have the two kinds of elasticity referred to above, besides the " Young's modulus," which is a composite of the two. If, however, a body though homogeneous has not got the same qualities in all directions, as, for instance, a crystal or a piece of wood, there will be found instead of two kinds of elasticity (volume and shearing) twenty-one kinds.

Prof. Albert Kingsbury.—It has been shown by Prof. J. B. Johnson ("Materials of Construction," page 6) that rubber is probably less susceptible to change of volume under pressure than any other known substance. His argument is based upon the fact that rubber does not appreciably change its volume under simple tension or simple compression Poisson's ratio being very nearly one-half for that material, while all other substances increase in volume under tension and decrease under compression. It would thus appear that the principal elasticity in the device described in the topical question was that of the tube in which the rubber was confined, the tube being subjected to internal pressure; and hence the resilience was very slight.

Mr. Suplee.—Professor Kingsbury's remarks lead me to mention a boiler tube expander which I saw many years ago in Philadelphia, built on that very principle.

This expander was made of a piece of rubber, much like a rubber car spring, with a hole through its axis, and a differential screw running through it so that it could be subjected to a very powerful axial compression. The rubber, being practically incompressible, expanded radially as the screw was tightened, and when inserted into a boiler tube it expanded the tube out into the tube sheet as effectively as any roller expander. The advice acted practically like a hydraulic press, in which the rubber took the place of the liquid, with the convenience that no provision was necessary against leakage.

Mr. Francis H. Richards.—I would like, incidentally to call attention to one or two points about the behavior of rubber. It is very difficult to get pure rubber which is entirely free of air or gases. Recently I had occasion to examine some specimens under a power of 50 to 100 diameters, and I found that rubber that had been absolutely untreated—not vulcanized at all—had a great many bubbles or air spaces. Most of these were very small; many were not more than a 1,000th of an inch in diameter. Of course there must be a great difference in the physical behavior under mechanical treatment of pure rubber and of vulcanized rubber, or of acid-cured rubber (which is practically a different product). These spaces may account for the slight variation in volume that rubber is sometimes supposed to have when treated as a fluid under high pressures. A large number of specimens were examined, and those small air bubbles were found in all the samples inspected.

Mr. Gus C. Henning.—The elastic resistance which a body offers to forces tending either to change their shape or their volume is identically the same in kind.

Let us assume that a block of material be subjected simultaneously to an end thrust and bending force. The former will immediately be converted more or less into the latter, and will act upon the material in a nearly identical manner with it. The resistance offered to these two forces will therefore be the same. This is caused by the shifting of the neutral axis of the material with relation to the axes of the forces applied. A thrust or crushing force resolves itself into bending forces immediately the axes of force and resistance do not coincide mathematically.

The above conditions obtain only when the material is free to move in one or more directions.

Let us now assume that this same piece of material, a cube, or, better still, a sphere be subjected to forces on all sides, each being, therefore, opposed by another of equal strength at all points of the body. Such forces cannot produce any change of shape, except equal changes toward the centre of mass, thus producing a smaller volume, and hence greater density.

It has never yet been proven by actual test, that material free from voids can be given a greater density under pressures calling into play elastic resistance only.

Those conversant with testing materials must agree with the statements in the following paragraph from Marten's "Handbook of Testing Materials," paragraph 25, page 14, viz.:

"25. A property of solid materials, which is of exceedingly great importance to the technologist, and for the further elucidations in this work, and which is also possessed by liquids, is that by which *they change their volume by only an infinitely small amount when subjected to external universal pressure, provided they have a degree of density*=1, *i.e.*; when they are free from internal voids; under these conditions they do not undergo a change of shape, so long as their internal structure does not provide resistances different in different directions. This important property makes possible, *e.g.* the phenomenon that even very elastic bodies such as rubber behave as though inelastic when they are surrounded by rigid surfaces, or are acted upon on all sides by forces tending to change their shape."

From this it will be seen that there is but "one kind of elasticity in materials," and that India rubber has practically none of the assumed second kind, even if it existed.

No. 149.

What has been your experience with oil burners?

Mr. W. J. Wilcox.—The Southern California division of the Santa Fé Railroad burn, on all their locomotives, crude oil which has an asphaltum base and costs $1 per barrel. It is received in large storage tanks from pipe lines and tank wagons, from which tanks it is pumped into local tanks near the track, whence it runs by gravity to a stand pipe, and is delivered to the engine.

The engine tanks are built with round corners on top and no coal space in front, the oil tanks being built in the water tanks, and holding about 7 tons of oil. They are supplied with steam coils for heating the oil to make it flow freely in cold weather, and are also connected with the air reservoir with pipes, check valves, and gauge and pop safety valve, where a pressure of 3 to 4 pounds is sometimes used to get a free flow of oil. The oil is taken from the tanks by means of a hose connection between engine and tender, the oil valves on the tender being connected with the engine by an automatic device which closes them in case the engine and tender part. The oil after it leaves the tank flows to a hot box, as it is called, under the engine deck, where it is heated by steam. The flow of oil from this heater is regulated by a stopcock manipulated by a rod running up through the deck to a brace about level with the throttle lever. The upper end of the rod is provided with an arm or handle, which runs around an arc or quadrant having teeth milled into it to hold the dog on the handle, which is operated by the fireman to regulate the flow of oil to the burner.

The burner, a patented affair, is called the Booth burner. It is about 12 inches long and 4 inches wide, and made of brass, having two passages cored in it, one for oil and one for steam, both of which enter at the back end. The front end has two openings, one for oil, 3 inches long and $\frac{1}{2}$ inch wide, and one for steam $3\frac{1}{2}$ inches long by $\frac{1}{32}$ inch wide, the steam opening being below, so that the steam carries the oil with it when the burner is operated. A globe valve within easy reach of the fireman regulates the atomizer, so called because it atomizes the oil in the fire box. The burner is placed under the mud ring at the back of the ash pan, which is partitioned with a false circular bottom riveted to the upper part of the sides, and dropping enough in the middle to take the burner. This partition, which is cast iron, is provided with three holes about 8 by 12 inches and 8 inches apart, through which the air enters the pan through dampers at the front and back below the partition, and passes up into the fire box, which has no grates. The pan and fire box are lined with fire-brick as high as the flues on the sides, front and back, and the brick arch extends from the front wall about one-third the length of the fire box; it has no opening in front or through it. The combustion takes place below the arch, and the flame passes around the arch and then to the flues. The fire door has a hole through its centre covered with a slide, through which the fireman cleans the flues when they become clogged with soot, with sand handled from a big-mouthed funnel having a spout at its bottom. The spout is placed in the hole in the door, and the sand is drawn into the flues by the exhaust.

The front-end arrangement is provided with a medium-height nozzle just below the centre of the boiler, over which is a conveyor petticoat pipe, netting and diaphragm plates being dispensed with. The same sized nozzle tips are used as with coal-burning engines. The best results are obtained when you can just see the least color of the smoke issuing from the stack. The fireman shuts off when the engineer does, or he has black smoke, and regulates his fire with the draft of the engine by the quantity of oil feed, the atomizer, and blower.

The heat from the oil is very intense, which makes it necessary to line the fire box, as above stated. If the steam pipes or boiler do not leak there is no trouble in keeping up steam, unless there is something else radically wrong with the engine, and the fireman's job is an easier one than the engineer's.

The engines average about 30 miles on freight and 55 miles on passenger service to one ton of oil, some having made more than 100 miles and some less than 25 miles in different service. The oil is measured in pounds, 8 pounds to the gallon, and 42 gallons to the barrel, which would be about six barrels to the ton, so the cost of one ton of fuel oil would be $6.

Measurement is made in the tanks by means of steel gauges, the amounts in the tank before and after taking, and the difference being charged to the engines first in inches, and, after calculating in the office, in pounds, each inch representing so many pounds.

Mr. Walter S. Arnold.—The burner which has proved most satisfactory, to my knowledge, is one which has been tested in this section, invented by Ernest M. Arnold, of Putnam, Conn.

The essential requisites of an oil burner using fuel oil in steam plants would seem to be these:

1. The complete atomizing of the oil.

2. The complete combustion of the oil before the flame enters the tubes of the boiler as thus soot is prevented from collecting in the tube.

3. The use of a jet of steam at boiler pressure in atomizing the oil as the steam (which, on entering the furnace, is decomposed into oxygen and hydrogen and thus is an aid to combustion), has the effect of preventing checking of the boiler surface which has been observed in many cases where oil is used without steam.

4. An arrangement of the parts of the burner so as to utilize hot air from the furnace in heating the oil before it leaves the burner as it has been found to atomize in a much better degree when heated.

5. The arrangement of the parts of the burner so that in case of foreign substances entering in the oil, it can be cleaned while in operation.

There are a great many kinds of burners on the market for using fuel oil, but the one I have referred to above is the only one that I know of that in actual practice has met these requirements.

Prof. Arthur L. Williston.—For a number of years oil burners were used at the Pratt Institute, and liquid fuel was used exclusively under our boilers for power, light and heat. Our experience, therefore, may be of some interest to the Society. The Reed burner was the one which was principally used and it was found very satisfactory.

Figure 91 shows the sectional view of this burner and the method of its operation. The oil is admitted through the small $\frac{3}{8}$-inch pipe in the centre, and the steam which is used to atomize the oil is admitted through the annular chamber marked *A*. The size of the opening through which the steam passes may be varied by turning the sleeve *B* either to the right or to the left, and thus moving the outer casing *C* backward or forward. The stuffing-box *D* is needed to prevent the steam from leaking at the back end of the burner. A limited quantity of air is admitted through the

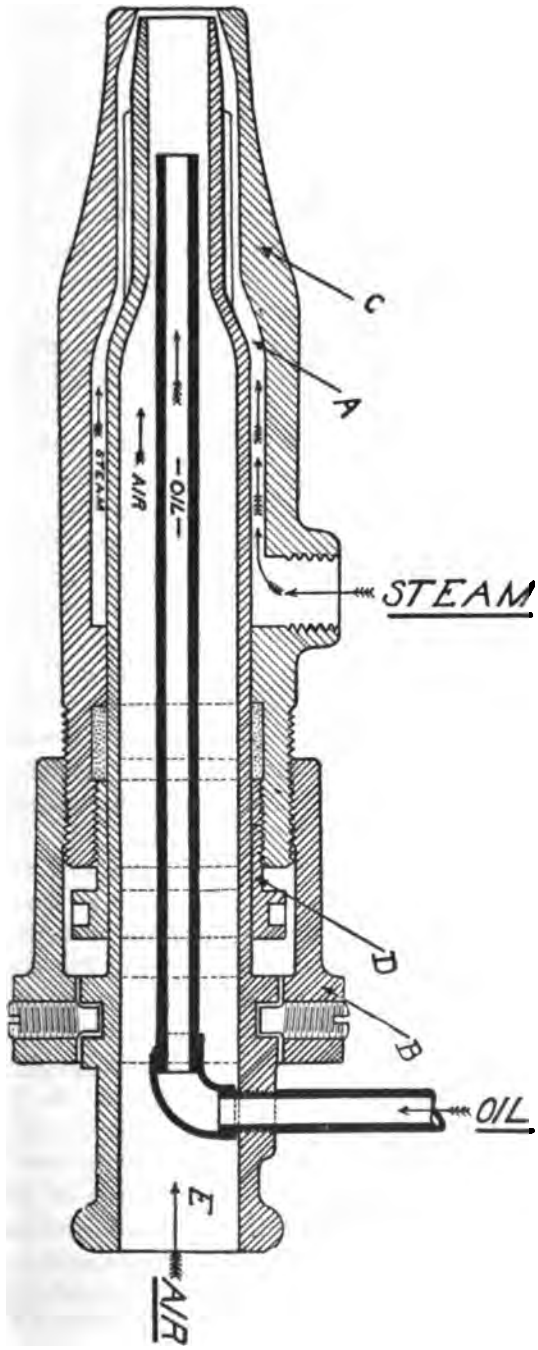


FIG. 91.

centre of the burner, as indicated at E, and this air has a good opportunity to become thoroughly mixed with the steam and with the oil as it is forced into the furnace.

The chief virtue of this burner is that it thoroughly atomizes the oil. Our experience with this and other burners showed that any burner which will atomize the oil will give good results provided the furnace is properly constructed. The most important thing is the furnace. With a good furnace almost any burner will do, and without a properly designed furnace I do not believe it is possible for any burner to satisfactorily burn oil in quantity. The time required for complete combustion is so great that it is necessary to have a very considerable volume to the flame, and it is practically impossible to atomize the oil so perfectly, and to mix all parts of the atomized jet with the right quantity of air so exactly as to have instant and perfect combustion throughout the entire mass. This condition is theoretically possible and may be very nearly attained in the small flame of a hand-blow pipe, but with the large burners that are necessary where oil is to be used as a fuel under boilers it is impossible; and no burner has ever been constructed that will accomplish that result.

It is necessary, therefore, where oil is to be used as a fuel, to construct a furnace of sufficient size to allow time for the complete combustion of the atomized oil before it leaves the furnace. It should also have provision for admitting the air needed for perfect combustion at different points, and should be so designed as to maintain in all parts a very high temperature.

The construction of the furnaces which we used at the Pratt Institute for a period of seven or eight years is shown in Figs. 92-94.* The oil is admitted through the two burners A and A^1, which are placed in holes drilled through the fire door. These burners are set so as to direct the flame against the fire brick incline B. A limited amount of air is admitted with the steam and oil through the burners, but additional air is supplied to each burner through the four openings marked C. As the flame passes over the bridge wall more air is admitted to it through the long, narrow opening marked D. And all along the bottom of the chamber between the bridge wall and the rear of the furnace setting there are a large number of very small openings through which additional air may be admitted to the flame as it is needed

* Credit should be given to Mr. Joseph Foster, chief engineer Pratt Institute, for the design of the furnaces described above.

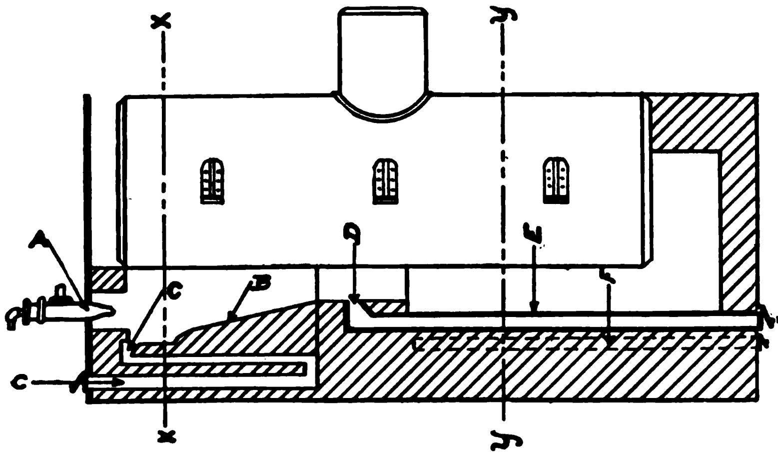
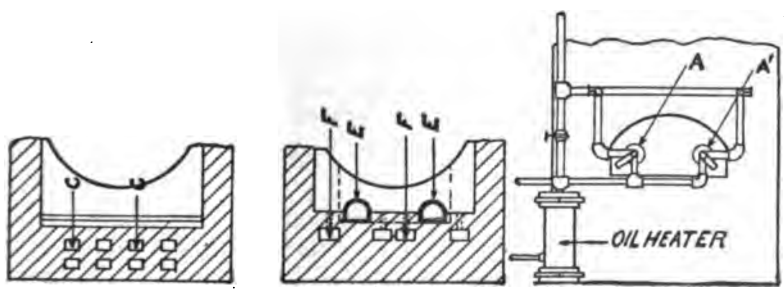


FIG. 92.—SECTIONAL ELEVATION.



SECTION XX. SECTION YY. FRONT ELEVATION.

FIG. 93.

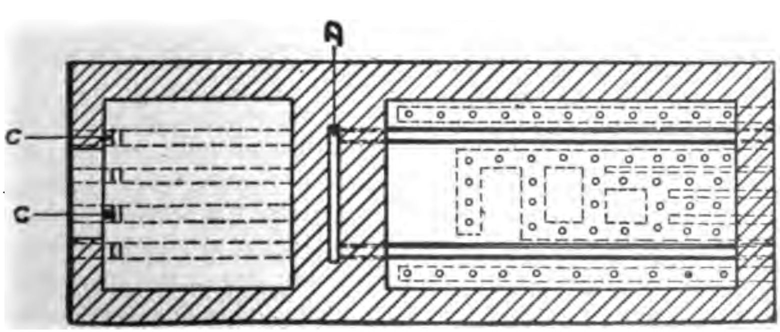


FIG. 94.—SECTIONAL PLAN.

for perfect combustion. All of these different sets of air openings are furnished with dampers which may be nicely adjusted so as to admit just the right quantity of air that is needed in each part of the furnace.

Mica peepholes were provided in different parts of the setting through which the fireman could watch the flame in all parts of the furnace, and with very little practice he was able to adjust the air supply as he varied the quantity of oil burned, so as to get perfect combustion with almost no excess of air. Under these conditions the whole setting would warm up to uniform temperature and the entire furnace, including the walls of the mixing chamber at the rear of the boiler, would become perfectly transparent and very bright red in color. A very slight change in the air supply above or below the proper amount would, however, disturb this transparency so that the fireman had no difficulty in nicely regulating the combustion.

With the dampers rightly adjusted, the products of combustion were entirely free from color and odor, and running the plant continuously from September until June, the flues would be found each June as clear as they were when we started up in September. After the setting was uniformly heated it would maintain its temperature for a long time. At night we would turn off the oil about thirty minutes before we wanted to shut down, at the time the plant was carrying its heaviest load, and the heat given off by the setting was sufficient to do the required work with no perceptible falling off in boiler pressure. And if we shut down at night with 90 pounds pressure we would find 70 to 75 pounds still on the boilers the next morning. The boilers were thus freed from the changes in temperature that the ordinary hand-fired boiler is subjected to. This, of course, is favorable to the life of the boilers, and during the entire time that we used oil as a fuel—a period of nearly eight years—not five cents was spent on any of the boilers for repairs.

Referring again to Fig. 92, it will be noticed that all of the air that enters the furnace has to pass first through long, narrow passages of heated fire-brick or tile. This, of course, helps to maintain the uniform high temperature necessary for perfect combustion. The passages that lead to the openings C are made by leaving spaces between the fire brick which are laid in the space that would ordinarily be used for the ash pit. This brick, after the fire has been started, becomes very hot and as the openings are small and the passages of air correspondingly slow, the air has a chance to be well heated before it reaches the flame at the burners. The two passages that lead to the opening in the bridge wall *D* are made of D-shaped tile, marked *E* in Fig. 93, which project upward into the furnace so as to expose as much surface as possible to the flame. The large number of small openings in the space between the bridge wall and the rear of the setting are made by making a small V-shaped nick in each brick, thus connecting the furnace with the hollow passages below, marked *F* in the figure, which lead to the rear of the setting where the controlling dampers are placed.

The oil is passed through the heater *F*, where it comes in contact with a steam coil and is heated to a temperature of about 180 degrees Fahrenheit, before it flows to the burners in order to have it vaporize more readily where it is atomized.

From this description I think it will be clear that the furnace had far more to do with the successful burning of the oil than the burner had.

In connection with the burning of oil as a fuel, I would like to add that there are very few conditions to-day, with oil at its present price, where it can be burned as cheaply as coal when all things are taken into consideration, especially in property which has to be insured.

For a short time during the present coal strike we were again burning oil at Pratt Institute, and a great many persons came to us to find out how we were burning it. They wanted to do the same thing. In every instance we asked them if they had considered the insurance question and advised them to find out from their insurance agent what increase in insurance they would have to pay if they were to burn oil. If they decided they wished to pay the increased insurance, and still wanted to burn oil instead of coal, we told them that we would be very glad to give them full information and show them just how to do it. Nobody ever came back for further information. That seemed to me to answer the question as to whether oil could be used to advantage under ordinary circumstances in this vicinity.

There is one place, however, where it seems to me oil may be used to a very great advantage, and that is in connection with the prevention or consumption of smoke. It requires but a small quantity of oil to create and maintain in a furnace burning coal a local temperature sufficiently high to make any smoke out of the question, if the oil burners and the furnace are so arranged that all the products of combustion from the coal will have to pass this point of local high temperature. The ordinary method of burning bituminous coal with a minimum amount of smoke consists of always keeping a part of the fire bright, so that the smoke and hydrocarbons given off by the part of the fire on which fresh coal has been thrown will be consumed as they pass over this bright part. The difficulty is to get firemen or mechanical devices to do this sufficiently well.

My suggestion is to merely use a jet of oil playing against the bridge wall or a fire-brick arch, or the back of the mixing chamber in the rear of the ordinary boiler setting, as a means of doing with some degree of certainity what the bright part of the ordinary fire is supposed to do, but what, in the hands of the ordinary fireman it does, as everybody knows, most imperfectly.

Where smoke ordinances are rigidly enforced, it would thus be possible by using a small percentage of liquid fuel to burn a cheaper grade of coal than would be allowed if coal were the only fuel used.

I have just spoken about using a small quantity of oil in connection with a coal fire, in order to insure the combustion of the smoke from the coal. There is no difficulty at all in a properly arranged furnace in consuming oil perfectly, provided the oil is capable of combustion. The oil we were using during the strike was a refuse oil, the same oil practically we used years ago excepting that now the refiners extract from the oil a great deal more than they used to, so that the refuse is much poorer than it was formerly. It contains now a much larger percentage of material which is absolutely incombustible, and as a result we are getting, not smoke, but a very delicate, fleecy white cloud from our chimney. It is pure white.

Mr. Kent.—What does the incombustible material consist of?

Professor Williston.—I don't know exactly.

Mr. Kent.—It is not carbonaceous?

Professor Williston.—No.

Mr. Kent.—I think Professor Williston is entirely right in saying it is not a question of the burner in burning oil; it is a question of the furnace. I had a conversation recently with a gentleman whose company had made extensive experiments in California in burning Texas oil. He says no one burner is better than any other, that all the burners are good when they are treated properly and all burners are bad when they are not properly handled. Any kind of a burner will burn oil and burn it satisfactorily and without smoke and without any trouble, provided you have this condition, that you only want to burn a very small quantity of oil, but as soon as you want to get up to commercial quantities of oil you meet with difficulties which are not at all overcome by changing the form of the burner, but they are overcome by building the furnace right and handling it right. There is no better burner, I suppose, than that of Urquhart made in Russia twenty years ago. Most of the others are copies or modifications of it. There is no essential difference except the flat flame burner, one of which was invented in Peru ten or twelve years ago. That form is also good. The statement made by Professor Williston about using an oil jet to kill the smoke of a coal fire is a new idea on the subject of smoke consumption. I hope he will give us a drawing showing how the furnace works and give us more of the theory. He says if we have a properly designed furnace and a smoky fire from coal, that by using a jet of oil we can stop the smoke. Others can stop the smoke by using a jet of steam. I will say that with a properly designed furnace and a good fireman you can have smokeless combustion without either oil or steam.

Mr. Fowler.—Speaking of the use of oil in connection with coal, Mr. Holden, the Superintendent of Motive Power of the North-eastern Railway of England, brought out a furnace a number of years ago, whereby the engines could be fired by oil or coal alternately, using a refuse oil; but he found, I believe, that when he was using coal, it was something of an advantage to cut down the oil supply to a very low amount and use a very little oil in the furnace in order to assist in stopping the production of smoke, but the furnace was made so that the fireman could fire coal up to a certain point and then run on his oil alternate with coal and oil as he pleased, and it worked very satisfactorily.

Mr. John Platt.—In naval work it is a great deal more necessary to use air pressure for atomizing the oil than steam, from the fact that it is very necessary that they waste as little condensed water as possible, I went into the question some time ago and one of the naval engineers in Washington said they could not afford to use steam for atomizing because it would make away with so much more fresh water, than when they made use of air pressure. I might add something with regard to what Professor Williston said in the using of small quantities of oil for preventing smoke, that is to say, for getting secondary combustion in boilers. In water-tube boilers for torpedo-boat destroyers built in Germany, they found they got often very great volumes of smoke. They built a secondary combustion chamber in the water-tube boiler by rearranging the bent tubes which they could easily do and then used an oil jet in connection with it. In this way, I believe, they very successfully overcame the difficulties which they had with smoke.

Prof. Albert Kingsbury.—In a discussion of this question at a previous meeting of the Society (vol. xvii. of the *Transactions*, page 318), I called attention to the fact that the Pennsylvania Railroad had found crude oil in every way desirable as a fuel for locomotives; but they did not adopt it because it would require about one-half the petroleum produced in the United States at that time (1885) to operate the entire system of the Pennsylvania Company.

Mr. S. Ashton Hand.—This matter of burning oil under steam boilers is a very alluring one. Some time ago I contemplated making a change in our steam plant so as to burn oil instead of coal, and wanted to find out about the best apparatus and method. I went to see the Standard Oil Company and asked them what was the best burner to use. They told me that all the burners on the market were good.

On questioning them as to the economy of burning oil their reply was rather an equivocal one. They said they did not burn oil themselves either under their boiler or stills. After some close questioning to try and find why they did not burn oil, they finally admitted that it was because coal was more economical.

Mr. Suplee.—This question of the use of air or steam brought out I think rather well in the report of Lieutenant Winchell, published in Admiral Melville's annual report, and treating of the tests made on the Mariposa. It was found there that the air pressure was more economical and satisfactory than steam. They had steam to use as reserve and used it on one or two days and got back to the use of air as quick as they could. There is a great deal of very valuable information in Admiral Melville's report for this year on the same subject.

No. 150.

Separating Oil from Exhaust Steam.

Mr. H. T. Yaryan.—I would like to call attention of members to the separator described on page 945, vol. xxi., *Transactions* of the American Society of Mechanical Engineers, as being all that can be desired in the way of an oil separator. Having used it for twenty years to separate entrainment in vacuum apparatus, and for the past six years as an oil separator for exhaust steam, I can speak from experience, and say that no trace of oil remains in the steam.

In construction, the rule should be that the tube area should exceed by 20 per cent. the area of exhaust pipe. The separator can be used when working condensing by attaching a pump to the drip, but under these circumstances the tube area should be double the area of exhaust pipe, and a gauge glass should be placed on the drip pipe to make sure that the pump does its work.

Mr. Charles Ekstrand.—I have found, after observations lasting over fifteen years, that the higher the temperature of the exhaust steam, the less oil can be separated, no matter what device is used. I found that, with the oil separators existing in the market to-day, and which are usually connected in the exhaust pipe between the cylinder and the condenser, a certain amount of condensation was separated, and the only oil separated was that due to the condensed steam. I have discarded all the so-called oil separators, and built an open tank with four compartments. These compartments can be filled with charcoal, coke, hay, or any other filtering material. The division plates are so arranged that the water to be filtered passes under one division plate and over the next. The air pump discharges into one end of this tank, and the water, after having passed through the filtering material, passes by gravity into the suction reservoir of the feed pump. In the feed pipe, between the pump and boiler, a coil of pipe is inserted inside the exhaust pipe, so that the feed water recovers by passing through this coil what it lost in temperature by passing through the filter. The surface condenser is boiled out with caustic soda once a year. I have found this arrangement very satisfactory, and in five years trial the boilers have been absolutely free from any indication of grease. My experience seems to show that oil can be separated from water at any temperature below the boiling-point, but I have not yet found an apparatus that would separate oil from steam at any temperature or pressure available in practice.

Mr. D. J. Lewis.—I have been separating oil by means of 6 Gudiron baffle plates placed in a box about four years, both on condensing and non-condensing engines, but I found out two things, that first you have got to have your baffle plates so that you can clean them; by that I mean, not just cleaning the surface, but cleaning the pores of the baffle plate. I find that they become saturated, and after the plates are thoroughly saturated the oil will go by. Separators are generally sold on sixty days trial, and as a rule they will clean up the steam in great shape in that sixty days, and the man pays the bill. About a couple of months afterwards he begins to find oil. I came up against that question. For a long while I did not know what was the matter. I started in experimenting. I first cleaned the surface with benzine. That fixed the plate separator so it would run about a week. Now we take our plates out and put them in a solution of soda and potash and let them boil about ten hours, and it brings them back to exactly the same condition they were in when they were first put in. We have had separators running condensing and non-condensing for two years, and they are in just as good shape as when they were sold. Another thing I found out was that on condensing engines it became necessary to throw a stream of water on the plate to separate the oil, and we got a result on the chemical analysis as low as one grain of oil to the gallon, but as I said the main point is cleaning the plates, and another thing is to have them so that they won't pick up the oil after it is separated.

Mr. F. Meriam Wheeler.—I do not know who suggested this topic, but I am glad to have it presented at this meeting, as the time is very ripe to ascertain what progress has been made since the subject was discussed before this Society seven years ago. It was at the New York meeting in December, 1895, and I well remember how much interest was manifested at that time—no less than 15 or 20 members taking part in the discussion.

Among the different speakers the following gentlemen referred to the various types of apparatus for filtering feed water from oil then in common use.

Mr. John C. Kafer spoke of the filter tanks on some of the Sound steamers, in which were used straw and hay, the result being quite satisfactory.

Mr. H. B. Roelker referred to a set of boilers that had been in use for about two years with practically no trace of oil, that were supplied with feed water filtered through common sponges packed tightly under some pressure—the sponges of course requiring to be frequently cleansed.

Mr. E. A. Darling seemed to think well of filters using "Excelsior" (wood) fibre, in that it absorbed the oil much better than straw or hay and could also be burned in the furnaces as fuel.

Mr. W. T. Bonner spoke of the ammonia-alum type of feed-water filters, which, although very nice in theory, he found that unless said filters were carefully watched they were very apt to make trouble with the boilers; he quoted a case where, in a short time, the feed pipes of the boiler were eaten out and the tubes badly pitted. His objection to filters using straw and other fibrous material is, that if the material is not frequently replaced, more or less oil passes through. Or, what is worse, there is considerable carrying along of the rotting filtering material with the feed water, which material would get under the pump valves, clogging the passage-ways, and causing no end of trouble. He truly remarked that, "Eternal vigilance is the price of safety."

Mr. P. H. Grimm brought forward a type of filter consisting of three cylinders, the feed water being passed first into one of these cylinders until it fills up within a few inches of the top. Then the water is led to the bottom of the next cylinder, and so on through the third cylinder, where it is drawn off near the bottom by the feed pump. From the first cylinder could be skimmed off considerable oil, which was in fit condition for use again; in the second cylinder there would be less oil, and in the third cylinder scarcely any. An illustration of this arrangement is shown by Fig. 62, on page 300 of the *Transactions* of the Society, vol. xv.

Mr. O. C. Woolson spoke of a very efficient feed-water filter that had been used in the West, consisting of a simple square vessel with a chamber at the bottom packed closely with hay.

Mr. H. A. Bang instanced a case in a Wall Street office building where a sand filter was used, and without alum or other chemical assistance the feed water was allowed to pass slowly through the sand and flow off at the bottom. This arrangement was quite efficient; but, of course, required frequent renewal of the sand.

Mr. G. I. Rockwood brought out the fact that it is quite a different thing trying to extract oil from water when used in boilers carrying very high steam pressure than when low steam pressure is used.

Mr. A. H. Raynal spoke of the importance of arresting all solid matter possible, which could be successfully done in most of the forms of filters named: he instanced a case where, with the use of the Johnson type of filter, he not only arrested vegetable matter but also a certain amount of mineral matter.

Mr. Boyer gave the results of his experience in filtering feed water in connection with refrigerating machinery. He brought out the fact that altogether too much oil is used by engineers, and instanced a case where a certain engine which had been supplied at the rate of eight drops of oil to every revolution of the engine, was cut down to one drop of oil to eight revolutions. He gave a very graphic description of a boiler that got into trouble with too much oil in the feed water, and where a lot of feed water heating pipes under the boiler gave out after running only four months.

Mr. C. L. Newcomb, Mr. Jesse M. Smith and Mr. W. A. Pierson, had considerable to say about the quality as well as the quantity of oil used in engines. They all agreed that it was very difficult to secure a uniform and satisfactory quality of cylinder oil that could be continuously relied upon.

Mr. John Fritz prefaced his remarks with the expression that, "This seems to be something of an experience meeting," and then went on to say that when he was a boy he had something to do with a small engine, which ran satisfactorily without the use of any oil in the steam cylinder.

Mr. James G. Winship followed in the same line and stated that an oscillating engine in the old Allaire Works ran for about 15 years without the use of oil.

When asked to give my experience with feed water filters, especially in connection with surface condensers, I called attention to the leading types of filters as then used in Europe, particularly in the naval and merchant marine service, and gave a brief description of the Rankin filter which is on the cloth-covered cartridge system, the Harris filter, which is fitted with sponges, and the Edmenston filter, which is a vessel filled with a number of perforated discs, provided with coarse towelling, a sectional view of which is shown by Fig. 63, on page 305 of the Society's *Transactions*, vol. xv.

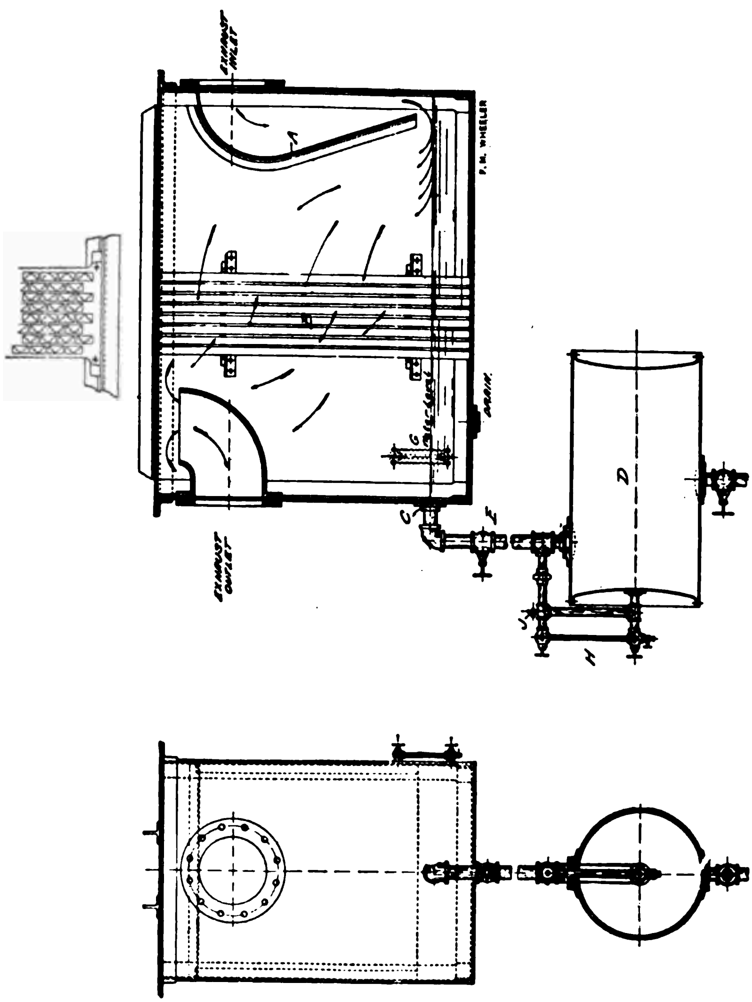
Since the time the above discussion took place there has been considerable advancement in the direction of providing good feed water. For instance, our friend, Mr. Snow, of the Standard Oil Co., and others, have brought out some very efficient filters of the chemical-mechanical type. Of course such filters require a great deal of room and are rather elaborate and expensive.

There has also been considerable effort made to eliminate the oil from exhaust steam in its passage from the engine to the surface condenser, and such efforts have been rewarded with more or less success. When I last visited Europe (a year ago last Spring), I heard of a very remarkable separator of this type in England, where they claimed they had been able to extract over 98 per cent. of the oil from the steam. I had a friend look the matter up, and after watching the apparatus a long time (it was in use at the Phœnix Works, Stockton) he reported that the amount of separation of oil averaged over 99 per cent. This filter was designed by Mr. W. J. Baker, of London, and consists simply of a large vessel, either cylindrical or rectangular in shape, with an arrangement of baffle plates in the centre. In the bottom of the vessel is carried a certain amount of water, as shown by Fig. 95. The exhaust steam enters at the right-hand side and is deflected downward by the deflector *A*, so that it is spread over the surface of the water, which latter is kept at a prescribed height in the bottom of the separator. This contact of the steam with the water causes a large portion of the oil to be deposited on the surface of the water. The steam then passes through the group of vertical bafflers, which are V-shaped plates (marked *B* in the sketch), where the remaining oil is eliminated from the steam, the latter passing out through the exhaust nozzle at the left. The oil is drawn off, together with a certain amount of condensed steam through the outlet *C*, and passes into the supplemental tank *D* shown below the separator.

When the tank *D* is filled, the oil can be drawn off without breaking the vacuum, by closing the gate valve *E*, and opening the gate valve *F* and the air cock *J*. If preferred, a small pump can be used in place of this tank.

Mr. Baker's separator differs from all others in that he insists upon a very large area for the steam to pass through, so as to reduce the velocity of the steam as much as possible. He claims that for want of proper room in the other forms of steam separators they have failed to do the best work.

He contends that steam may be divested of all the oil it contains, if the steam is allowed to expand and travel at a slow rate of speed, as by doing so the particles of oil have a better opportunity to adhere to the deflector plates and draw off properly. Of course



SECTIONAL VIEW OF RECTANGULAR TYPE OF BAKER OIL SEPARATOR.

FIG. 95.

this arrangement is practically prohibitive in a steam vessel, where the space is very limited, but for stationary plants it is entirely feasible.

To give an idea of how much room is required, I cite the case of a compound engine, where the "Baker" separator was about three times the volume of the low pressure cylinder. However, this was provided for by placing the separator under the floor.

The advantage of this system is the fact that it requires little or no attention and can be made to do its work automatically. What we need for eliminating oil is something that is thoroughly practical and that does not require so much attention from the engineers, as is the case with filter boxes, or similar devices for filtering the feed water where the filtering material has to be frequently cleaned or renewed.

As I remarked in the discussion we had at the 1895 meeting: "The average stationary engineer seems to begrudge the trouble necessary to attend properly to a feed-water filter of the ordinary type, although his brother engineer on the steamers takes it as a matter of course and as part of his regular duties."

Therefore, any device that requires little attention is very much to be desired, even though it may take more room and may not be very sightly in appearance.

One of my friends has recently suggested that oil might be separated from feed water by a centrifugal machine, such as the DeLaval cream separator. I desire to ask if any one has tried any experiments in that line. There is no doubt but what oil will be used less and less as we perfect the valve gear of steam engines. In fact many vertical engines are now in use where no oil whatever is used. That is where the steam turbine has the great advantage, no oil being required. However, as long as we have to use oil, as is the case with most steam engines, especially of the horizontal type, let it be of the very best quality, used as sparingly as possible, and then have a properly arranged steam separator of proper design placed between the engine and condenser.

Mr. James Christie.—The firm I am connected with are making quite successful machines now which separate mechanically, and do it right along automatically.

Mr. E. P. Bates.—I would like to ask what the experience of the members has been in separating the oil from exhaust steam after being used by the Westinghouse engines. I have had very little trouble in separating oil from exhaust steam used in the ordinary engine, the common slide valve on the Corliss and other makes, but I undertook to do this at one plant where the Westinghouse engine was used, an engine of considerable power, I think 250 horse-power nominal. The lower part of the bed is a reservoir for water and oil, and the connecting-rod and crank-pins run into this solution and it seems to be driven up into the cylinders of the engine and works through into the exhaust steam in considerable quantities, and any apparatus which I was conversant with at the time failed to remove the oil from the exhaust steam and the condensed water, and it became impossible to use it in the boilers under these conditions. If there is anyone here who has had experience in that line and has succeeded in removing the oil under similar condition, I for one would be very glad to hear from him.

Mr. Lewis.—I have used our separator on the Westinghouse engines and we have to clean plates twice as often. Where we generally clean the plates every thirty days, we do it every two weeks on the Westinghouse engines.

Mr. F. H. Laforge.—It is my business to inspect boilers, and in my work I have examined a great many where the exhaust steam from the engine has been returned into the boilers. I have seen different so-called separators used to prevent the cylinder oil returning with the steam. Some of them do take out a part of the oil, but there is still enough left to be, in my opinion, very objectionable.

Mr. Lewis.—I believe the question is separating oil from the steam. When they take oil out of steam they also take any water that is in the steam. But I think we have something like 4,000 separators working now satisfactorily, and they have been passed by the boiler insurance company; that is, they allow us to put the water back in the boiler. That was taken up by Mr. F. B. Allen and he made an exhaustive examination of it, and since we have been boiling the plates we have not had any trouble.

Mr. William Kent.—I have had occasion to look into the subject about two years ago. I put a separator in the exhaust pipe, and at the other end of the system, the exhaust steam being used for heating, returned the water back to the boilers, put between the feed pump and the boilers a feed-water filter with Turkish toweling in it, and that combination, the separator in the exhaust pipe and the filter at the other end, has worked perfectly for more than a year. The filter is universally used on ship-board.

Mr. Lewis.—One thing I forgot to say, that the separator should be placed between the engine and the feed-water heater. My experience is that if you put the separator beyond the feed-water heater, you cannot get the same results. You want to get the steam into the separator just as hot as possible.

No. 154.

Tempering and Annealing Steel.

Mr. H. P. Jones.—While recently engaged in the design and construction of annealing furnaces for annealing metals by a patented non-oxidizing process, the invention of Mr. Horace K. Jones, of Hartford, Conn., I had opportunities of discussing the subject of annealing with many superintendents, and also of studying many different methods of annealing, but in nearly every case I found that much difficulty was experienced in obtaining well annealed tool steel.

A difference of opinion seems to exist as to whether the producer or consumer of tool steel should do the annealing. The producer holds that the consumer alone is able to judge as to the correct heat to give the softness that he requires, and in favor of this it may be noted that the term "soft," as applied to tool steel, is widely construed by different consumers. The consumer contends that he should be able to purchase satisfactorily annealed tool steel, and that on account of large output, and therefore presumably perfected facilities for the operation, the producer is in a much better position to do the annealing.

This is certainly a just view from the standpoint of a consumer of small quantities, to whom the first cost of a suitable furnace might appear a considerable item. As a matter of fact, well annealed tool steel is often obtained from the manufacturers, but other lots of very imperfectly annealed steel are also so frequently obtained, that in a majority of the shops which came under my notice the practice of reannealing all tool steel was followed.

During the process of annealing, the quality of the steel may be injured by contact with furnace gases or by burning or overheating, and the efficiency of the operation may be diminished by under-heating or too rapid cooling. Judging from tests made upon specimens annealed in contact with different gases, and also from results obtained in annealing very delicate work, such as wire for the hairsprings of watches, in a similar manner, it would seem that, aside from oxidation due to direct contact with the flames, the injury that might arise from contact with gases is of little importance. The tests above referred to were described in the *Engineering News* of January 2, 1892, and in the *Engineering and Mining Journal* of January 9, 1892, and I will therefore but briefly state the manner in which the specimens were treated. The object of this process was to turn out a perfectly bright or non-oxidized product, doing away with all pickling, and its principal feature consisted in enclosing the metal in wrought-iron tubes or retorts of various sizes, and keeping these retorts in communication with a gas-holder or gas main during the entire operation of heating and cooling, the gas thus acting as a non-oxidizing atmosphere. As this arrangement permitted the gas to expand back into the main, a low pressure was maintained, an essential condition in a process of this character.

It was known that nitrogen should have no effect upon the metal, while the constituents of illuminating and other gases might injure it. A comparison of tests of specimens annealed in nitrogen, with those of specimens annealed in other gases, failed to show any important difference, but, compared with tests of specimens annealed in an open fire, the latter results were much inferior.

In a series of tests upon structural steel, Mr. Gus C. Henning makes the effect of improper methods of annealing very evident. (See " Treatment of Structural Steel," *Transactions* of the American Society of Mechanical Engineers, vol. xiii., p. 577, etc.)

Although, as above stated, this process was intended for bright work, yet it was soon found that tool steel, treated in this manner, using common illuminating gas, worked up much better than when annealed in charcoal or in other ways. The scale commonly found upon the steel, as it comes from the steel works, was also reduced and softened by the treatment, and the wear upon cutting tools ordinarily due to this cause was much diminished. But a most important result obtained was that of uniformity. Steel annealed at *different* times was *uniformly well annealed*, and I consider this the chief element of success.

By inclosing the steel in a retort all contact with the flame and resulting burning or oxidation of the steel was avoided, and any draught or variation of the heat was not communicated directly to the steel. The retorts were heated to the required temperature, depending upon the quality of the steel and the degree of softness to be attained, and then kept at this heat for a time in order to allow the heat to " soak " through the centre of the mass. The steel near the outside of the retort was not over-heated, and the entire mass was uniformly annealed. Much of the success was, no doubt, due to the care exercised in designing and constructing the furnaces. Oil was preferred as a fuel, and the burners were so arranged as to give the most uniform heat possible. There was no difficulty in determining the correct degree of heat from the color of the retort, but if desired a pyrometer could be used, thus eliminating all possibility of an error of judgment.

In order to obtain the best results the finer grades of steel admit of none but the most positive and certain treatment. The unsatisfactory results that are so frequently obtained are but natural consequences of either a disregard for the susceptibility of fine steels to the chemical and mechanical action accompanying higher temperatures, or an inefficient adaptation of means for removing or overcoming these injurious effects. As many tons of tool steel are being annealed in the manner thus briefly described, and at a comparatively slight expense, I bring these facts before the members of this Society, thinking that they may, perhaps, be of interest, and also prove that with carefully designed furnaces and means for the protection of the steel from direct contact with flame and oxidizing gases during the heating, and at least the earlier part of the cooling period, tool steel may be annealed perfectly and uniformly.

Mr. E. R. Markham.—When a piece of steel is heated red hot and plunged in a cooling bath it becomes very hard. Now, hardness is the quality desired in order that the steel may be able to perform the duty expected of it, but it not only becomes hard; it is also made brittle, and brittleness is not a desirable quality. In order to reduce the brittleness to a point where it will stand up and do the work expected of it, it is necessary to reheat the steel somewhat. Steel is very sensitive to the action of heat, commencing with cold steel, every degree of heat given it affects somewhat the structure of the steel.

If steel is hardened and subjected to strain when cold, it will be found, if tested in a testing machine, to break easier than if heated to a temperature of 100 degrees and tested at that heat, but if it is allowed to cool to the temperature of the first piece mentioned, it will break at about the same strain as that piece. It is presumed that both pieces were hardened at the same time, at the same temperature, and as nearly as possible under the same conditions, thus proving that the steel, although tougher when at the temperature mentioned, was as brittle as the piece which had not been reheated, when both were at the same temperature.

I have made experiments with hardened steel reheated to different temperatures from 100 degrees to 430 degrees Fahrenheit, and find that steel reheated to a temperature less than 175 degrees does not show any marked difference in the amount of force necessary to break the piece when it is cooled to the temperature of the room in which the experiments were made, but beyond that temperature, a difference was noticeable, every 25 degrees given the piece making a marked difference in its strength. It was also noticed that the higher the temperature was raised, the more rapid the changes in strength. This is especially noticeable in two pieces, one drawn to 300 degrees and the other to 350 degrees, a difference of only 50 degrees.

My own experience has never shown any tools which required having the temperature drawn to have the brittleness sufficiently reduced to enable them to stand up when in service unless heated to a temperature of 200 degrees, and as the difference in strength between a piece heated to this temperature, and a piece hardened at the same time and under the same circumstances, and heated to 212 degrees, was not noticeable, we always drew them to the latter temperature because it was accomplished so easily, as we had a tank of water always kept at the boiling point (212 degrees), into which we dropped small pieces as they were hardened to keep them from cracking as the result of internal strains incident to hardening. The length of time the pieces were subjected to this temperature did not appear to affect the brittleness appreciably, provided they were left in the liquid long enough to become heated uniformly throughout.

My attention was first directed to the fact that hardened steel could have the brittleness incident to hardening reduced at a temperature lower than that necessary to produce a faint straw color (430 degrees), by an experience which I made mention of in an article in the *American Machinist* a few months ago. A circular forming tool used on an automatic screw machine would not stand up when left as it came from the bath, as one of its cutting portions was a slender projection. When drawn to a straw color, even the faintest, it would not do the amount of work we thought it should. I reasoned that if the difference of 30 degrees between a faint straw (430 degrees) and a full straw color (460 degrees) produced such a marked difference in the hardness of the piece, as it showed when tested with a file, and if reheating the piece to 430 degrees made it too soft, then there must be a point somewhere between a dead hard piece of steel and one drawn to the temperature mentioned, so I set about experimenting and found that if I drew the temperature to 212 degrees the tool gave excellent results.

We tested pieces of steel left in the tempering liquid ten minutes at the desired temperature, and others left in one half hour, and found no apparent difference in hardness or strength, although, as mentioned, our method of testing for hardness was somewhat crude, and could not be relied on for accurate results.

It was a very difficult matter to test the exact hardness of the pieces without any means at hand, although we rigged up a crude testing machine, which consisted essentially of a base having a vise to hold the hardened piece of steel, a diamond was set in the end of a bar of steel; this was hinged to a lever which was above the vise; on the end of the lever we hung weights, thus bringing pressure on the diamond, as I had no idea in mind only to test the pieces in order to find a point where certain effects would be produced. I kept no account of the weight necessary in order that the diamond might scratch the pieces heated to the various temperatures; our tests were all relative tests.

There seemed to be no marked difference in the weight necessary to make the diamond scratch a piece of steel as it came from the hardening bath, and one heated to a temperature of 185 degrees. Beyond this, and up to 250 degrees, there was very little difference in the apparent hardness of the piece, although there was considerable difference in the amount of force necessary to break the two, showing that hardness and brittleness were not reduced proportionately, according to the results of our experiments. On an average, we daily drew the temperature of 350 pieces of work to 250 degrees. These pieces would not stand up if left as hard as when they came from the hardening bath, neither were they hard enough if drawn to the faintest straw color.

The next temperature that I have a record of drawing work to is 325 degrees. There was very little difference in the hardness of the pieces drawn to this temperature and those drawn to 250 degrees, but there was a very marked difference in the strength of the pieces. These pieces would not stand up if drawn only to 250 degrees, yet stood very nicely when drawn to the temperature mentioned. We averaged drawing 500 pieces of work daily to this temperature.

The next temperature shown in my record book to which work was drawn, is 350 degrees. This piece was not of a shape that allowed us to leave it at 325 degrees, as it was not as strong, and was subjected to greater strain, yet we found that at 350 degrees it gave good service. Under test it showed somewhat softer than the pieces drawn to 325 degrees. This seemed peculiar to us, as, the piece being lighter than the other, it should, according to the generally accepted idea, harden harder than the other, as they were made from the same steel and from bars of the same size; in fact the steel came altogether, was put in the same rack, and was exactly alike so far as results depending on the nature of the steel was concerned.

Other temperatures used were 375, 400 and 415 degrees. These, however, were seldom used, as they were the temperatures to which we heated swaging dies for various purposes.

It is surprising to note the difference in the strength of the various makes of steel, when hardened at *their* refining heat and drawn to any one of the temperatures mentioned. It is also surprising to note how much faster some makes of steel soften than others.

One fact that was especially noticeable in our experiments was, that the steels which gave off their surface carbon the most readily when heated exposed to the air, were softer when drawn to a given temperature than those which did not, even when they were heated away from the action of the air and the products of combustion in the fire.

It was also noticed that steel which was over annealed, that is, heated for too long a time when annealing, was softer when drawn to a given temperature than a piece of the same steel when heated just long enough to accomplish the desired result.

The amount of heat given steel when hardening seriously affected the results, but by proper methods of heating when hardening, we were enabled to heat the steel very nicely to the temperatures which refined the steel, and made it the strongest possible. We found that this heat varied in different makes of steel, even when they were of the same percentage of carbon.

Mr. Oberlin Smith.—It seems to me that the paper is not of a very comprehensive character. Although the facts are interesting so far as they go, the sizes and shapes of the pieces hardened are not stated to an extent enabling many comparisons to be made.

There is a general idea that dipping a piece of red-hot steel into oil hardens it. I think it is understood it will not be as hard as if dipped in water, but there is a good deal of fallacy in regard to the conclusions drawn. Taking the ordinary tool steels, averaging about one per cent. carbon, we can harden the points of turning-tools and the sharp edges of milling-cutters and the sharp corners of small cubical pieces by simply having the metal at a bright red heat and dipping it in cold oil; but if we take something approximating the shape of a large sphere or a cylinder of considerable diameter, with rounded ends, we will find very often that we do not get it hard at all. In " chunky " shapes, any sharp corners, or rather projecting parts, will harden while the main body will not. I have had some experience in hardening rings for dies of various kinds. These rings would average from three inches to a foot in diameter, with a cross-section at each side of perhaps one inch square to two inches square. Rings of this kind will rarely harden in oil to much extent. They are, of course, a good deal harder than if laid down and allowed to have an " air-temper " merely. They can usually be filed freely, and are about as hard, in many cases, as if dipped in water and then drawn down below " a blue." It is not, therefore, much of a practical question how many degrees of heat will draw a piece of steel to the proper temper to make it strong and tough, until we find out how hard it is to start with—from the original dipping.

Of course, people who harden drills and turning-tools and such things in oil generally get them hard enough because the edges are very thin and it does not matter whether the body of the tool is hard; indeed it is better soft. In the case of knife-blades, clock-springs and such we have the metal all thin, and there is no trouble in oil hardening, as the heat is removed quickly. It seems to me that almost the whole question of hardening, with a given quality of steel, is the quickness with which the heat leaves the metal when it is going from a bright red to a very dull red. After that stage it does not make very much difference what happens. It is all a matter of the quickness of the initial cooling. That is, of course, the reason why we have such greater hardness when red-hot steel is dipped in mercury, because mercury is doubtless the best conductor of heat among cold liquids. With dilute sulphuric acid and, to a less degree, with salt water we get good hardening, because these liquids are good conductors. Plain cold water comes next, and warm water follows. I don't think chemical composition has much to do with it, and hence would eschew quack hardening fluids.

We can get a great deal better hardening results in rings and such things if we squirt a heavy stream of water at or through them than by dipping them. Taking steel of 80 or 90 per cent. carbon, small pieces will harden in water and large ones sometimes won't harden at all, unless we squirt on them a tremendous stream at high velocity. In hardening large punches and dies if we use a mixture too high in carbon (to insure hardening in almost anything) the steel is very apt to crack; but using 100 per cent. or lower, to get it crackless, so to speak, it is difficult to harden it at all without a stream of water. This simply carries away the heat faster than does still water, which gets warm locally around the steel.

There are other liquids between water and oil of various merit; but, after all, it seems to be only a matter of *how fast* the heat is taken away from the steel. Before formulating any general law about it we must know, firstly, what the quality of the steel is; secondly, the conditions under which it is dipped; and, thirdly, in what kind of a liquid in regard to conductivity of heat. Oil is a sluggish conductor, and very tricky unless we know by experience the shape of the particular pieces of steel suited to such an environment.

Professor Williston.—Mr. Smith has called the attention of the Society to the great difference in the results that are obtained with pieces of steel of different sizes and shapes when they are hardened in different liquids, assuming, I suppose, that they are all heated uniformly and to the same temperature before being quenched. In this connection the experience of some of the larger manufacturers of knives for wood-working machinery, veneer cutters, paper-cutting machines, etc., would, I think, be of interest.

These large knives have to be hardened with a very great degree of uniformity for any single line of work, but as they are used on machines which are operated at widely varying speeds, and for cutting all sorts of materials, the treatment that is best for one set of knives may not be at all suited for another. A very considerable range of treatment both in hardening and in tempering is, in fact, required to meet these conditions. And the conditions have to be met with great exactness, because when a given customer, say a maker of some woodworking machine, has found, after a costly experiment, a knife which exactly suits his purpose, he wants to be able to duplicate that knife with certainty.

The method of hardening which has been found to give the best results for this purpose, is not the one which has been suggested of heating the steel all to the same temperature and then cooling it at different rates by quenching it in different liquids, but instead to get this desired variation in hardening by heating the steel before quenching to varying temperatures and cooling it in every case as rapidly as possible, in cold water or brine, with a forced circulation. If a very hard steel, and one somewhat brittle in consequence, is wanted, the temperature before hardening is high. If a tougher steel, corresponding more to an oil temper is wanted, the original temperature to which the steel is heated before quenching is proportionately lower, but still the effort is made to cool it just as rapidly and in the same way as in the case before. It is found that the temperature at which the different knives should be hardened must be determined accurately, and some of the best makers are now using electrical pyrometres for this purpose, and are keeping a record of the temperature to which each set of knives is heated before hardening so that more knives of exactly the same quality may be furnished in the future.

Regarding the question of drawing the temper, it is found that a few degrees variation in the temperature to which the steel is heated in drawing, will make an appreciable difference if it has all been hardened uniformly. The method which is used is to draw the temper of every knife by heating it in an oil bath, keeping a record of the maximum temperatures measured with a mercury thermometer. The lowest temperature at which there is a noticeable effect on a piece of hardened steel is about the temperature that was mentioned in the first discussion, but the lowest temperature at which steel is drawn in knives which are put upon the market is about 200 degrees Fahrenheit. And according to the purpose for which the knives are to be used the temperature at which they are drawn varies all the way from this point up to nearly 500 degrees Fahrenheit.

It is found that within reasonable limits it makes no difference how long the steel is heated either in the process of hardening or in drawing the temper, provided the time is sufficiently long for the steel to be hardened uniformly, and provided the maximum temperature is always the same. By using the methods just described we could attain much nicety if the quality of the steel is kept the same.

Mr. Rogers.—I have had considerable to do in this line, an uncertain proposition. Some years ago I had a Government contract and the inspector worked a proposition which was a good deal worse than the metric system and rejected my goods. He used a magnifying glass on all my goods. Investigating the trouble, I ran across some written data by the late George F. Simonds, and it explained the uses of a great many boxes which I found about the plant which had "windows" in the sides of them which nobody could account for, and I put these into use. Those boxes were of that form, and in his hidden paper he explained the apparatus. He filled the boxes full of brine first, and then from below he filled them up with oil, so that the brine was raised that much higher and left a space in the bottom full of oil. Then he had a basket for hardening small pieces made of wire with a handle, and he took the steel from the case-hardening furnaces and dumped it in the basket, sent in through the brine and brought it up in the oil. We put that apparatus back into service and never afterwards did we have a single rejection of the work, or trouble, because we had eliminated the space of time in the air going from the water bath to the oil bath, and after that we had no further trouble. The microscope exhibited no water or fire cracks. I also found that it cut down our cost of production, because before we had to reheat and draw it, but here we took it right from the furnace. That also avoided a great deal of warping. I think it is one of Simond's patents, but I am not sure.

Mr. Bates.—At what temperature did you keep your bath?

Mr. Rogers.—We started with the bath cold and got it so hot that we could hardly put our hands in it. We would always keep the temperature in the furnace even for about two hours after the pots in which the hardening was done became cherry red. Of course it would depend a great deal on the heaviness or lightness of the work that had to be hardened, and the quality of it. It was all machinery steel. We had previously, made milling-cutters of machinery steel and case-hardened them for special jobs, and always had trouble with the teeth flaking off or breaking, but after we commenced case-hardening by this method we had no further trouble, and Simonds in his documents said that this would cut down the cost of the labor required, and would also eliminate the water and fire cracks.

Mr. Charles L. Gabriel.—I would like to ask Mr. Rogers how long he left the work, what interval of time elapsed after passing between the water before he drew the basket up into the oil.

Mr. Rogers.—That depended upon the thickness or the fineness of the work. Some work would be $\frac{3}{16}$ of an inch thick, and we would hold it in the oil not over five minutes. Other work that was thicker we discovered by experiment took longer, as Mr. Simonds said nothing in his paper about time.

Mr. Gabriel.—Of course this only applies to a case where you do not put any subsequent heat into the article after it comes out in the oil.

Mr. Rogers.—We found we did not have to put in any subsequent heat by using this process. By adopting that we cut down our cost of production. You can easily see how much it saves.

Mr. Gabriel.—I would like to ask, while I have the floor, if any of the members present can give any information as to the best results obtained in hardening dies for stamping flat ware, such as spoon work, from silver and German silver? And what is the best result which has been obtained by any method of hardening.

No. 969.*

THE USE OF A SURVEYING INSTRUMENT IN MACHINE SHOP PRACTICE.

BY CHARLES C. TYLER, PITTSBURG, PA.
(Member of the Society.)

1. MANY machine shops now have floor surface plates upon which large work is laid out and various machining operations are performed by the use of portable machine tools secured to the plate. The quality of the work produced is largely determined by the accuracy of the laying out, the correctness of the portable tools, and the trueness of the surface plate.

2. For work having moderate dimensions, scales, squares, beam-compasses, and straight-edges can be purchased in the market sufficiently accurate, if used by careful workmen, to meet the average requirements in laying out the work and setting the portable tools; but for work having large dimensions the scales, squares, beam-compasses, and straight-edges become quite special, are expensive, and require the utmost care in their manipulation to insure correct work. Ten-foot steel squares and beam-compasses spanning twenty-five feet are not easy tools to make or handle, and the fear that errors might be made in some large work, to be undertaken at East Pittsburg, led the writer to the consideration of doing away with these abnormal tools and substituting others more easy to manipulate and of a kind to insure accurate results.

3. The method decided upon has proved so reliable and satisfactory for nearly two years that a description of it may contain some suggestions of benefit to those using surface floor plates and portable tools. To carry out the method referred to we shall require a dividing and levelling instrument of somewhat special construction; for mounting the dividing instrument, a centre column (with a taper hole whose axis is exactly perpendicular to

* Presented at the New York meeting (December, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

the base of the column), a centre gauge, a straight-edge, several specially ruled targets, a surface gauge, and other small tools.

4. Let us assume that we have a surface floor plate, suitable portable vertical slotters or planers, and portable horizontal drilling and milling machines, and that we are to construct a cast-iron ring of over twenty feet outside diameter, properly proportioned. This ring is to be made of six similar sections suitably cored and ribbed, and the only operations to be described are the accurate planing of the joints, cutting the keyways, and drilling the holes for the clamping bolts.

Mount one section upon planed cast-iron blocks about two feet thick and fasten securely to the floor plate, being careful to equalize any warped surfaces found in the casting. The centre column is to be moved about upon the floor plate until its exact position in relation to the section has been determined by the use of the centering gauge, and the column is then to be securely fastened to the floor plate, where it should remain until all the operations upon the section have been completed. (See Fig. 99.)

5. Mount the dividing instrument upon the centre column, and with the telescope determine the correct position for the zero division of the divided circle, to insure equalizing the cut at each joint surface, and clamp the circle in this position. The next move is to secure a straight-edge or parallel to the floor plate in such a position that its front edge is in exact alignment with what is to be one finished joint surface. The location of the straight-edge is determined by the dividing instrument and by the use of a special target which rests upon the top of the straight-edge and has a zero line exactly in alignment with a shoulder which touches the front of the straight-edge. (See Fig. 100.) Another straight-edge is then to be secured to the floor plate under the other joint of the section, and its front edge must be set at exactly sixty degrees from the first straight-edge; its position being determined by the dividing instrument and the special target used in the previous case. The accuracy of the location of both straight-edges being demonstrated by proof surveys, we are ready for planing the joint surfaces.

Planing the Joint Surfaces.

6. For the joint planing operation let us use a portable vertical slotter or planer having the front edge of its base exactly parallel

with the horizontal travel of the tool slide. Secure the portable slotter upon the floor plate with the front edge of its base exactly parallel to the front edge of the straight-edge; the accuracy of the setting being easily determined by a pin gauge, and the fine adjustment being obtained by screw jacks bearing against the base and stop lugs inserted in the floor plate. While the roughing cuts are being made upon one joint surface, set a second portable slotter by the other straight-edge in the same manner and proceed with the roughing cuts at this end. In order that the workman while roughing may not cut beyond what should be the finished joint surface, it is advisable to scratch a finish line on the rim section at each joint, but the setting of the tool for its finishing cut is more easily and accurately made by the use of the telescope of the dividing instrument than by any other plan yet tried.

7. Before setting the tool for the final finishing cut it may be thought advisable to prove the surface of the last cut—a much simpler matter than at first appears. Let us suppose the last cut has left two-hundredths inch stock to be removed and that we have a target with a centre line adjustable in a line parallel with one edge. By resting the edge of the target against the surface and adjusting its centre line until it exactly cuts the centre of the cross lines of the telescope when set at the correct angle, we can survey the joint surface and prove that it is or is not parallel with what is to be the finished joint surface. If the surface be found correct, the finishing cut can be made at once; if there be an error, proper adjustment of the portable slotter must be made and the joint surface again surveyed after taking a light cut. The accuracy of the finished joint surface can easily be determined by the dividing instrument with suitable targets.

Cutting the Keyway.

8. If the keyway is to be cut parallel with the face of the rim section, the operation can be performed by a portable horizontal milling machine or a portable slotter having a horizontal movement to the tool slide—the correct setting of either machine to be governed by the straight-edge attached to the floor plate, and the exact vertical location of the keyway determined by a surface gauge.

If the keyway is to be cut parallel with the axis of the rim section, the portable slotter can be used advantageously and the exact distance of the keyway from the centre of the ring determined by a pin gauge calibrating from the tool to a pin inserted in the taper hole of the centre column.

Drilling the Bolt Holes.

9. The axes of the bolt-holes should be perpendicular to the joint surface, and they can easily be made so if the front edge of the portable horizontal drilling machine be perpendicular to the travel of the spindle and the base of the machine set parallel to the straight-edges attached to the floor plate. The exact position of each hole is better determined by a jig located by the keyway and a scratched centre line; but if the jig is thought too expensive, the holes can be quite easily laid out in the usual way.

The Other Ring Sections.

10. For each of the other five sections the same process should be gone through, and it will be found much easier to adjust the centre column and straight-edges than to attempt to locate each section.

Testing Portable Machine Tools.

11. By the aid of the dividing and levelling instrument it is easy to test the accuracy of portable machine tools. In the case of a portable vertical slotter the vertical travel of the tool slide can be determined by setting the instrument so that the cross lines of the telescope exactly cut a line drawn upon the tool block when at its lowest position. Elevate the tool slide to its highest point, tip the instrument, and note the position of the line on the tool block in relation to the cross line of the telescope. If the tool travel is in a line perpendicular to the base, and the instrument has been properly levelled, there will be no variation in the reading. If the tool travel is not perpendicular, the instrument indicates the error, and correction can be made in the portable tool itself or shims can be used under the base to correct the error. To test the parallelism of the transverse travel of the tool slide with the front edge of the base of the machine, set the front edge of the base parallel with a straight-edge secured to the floor plate in a surveyed position—one edge of the straight-edge being approximately perpendicular to the tool slide. Adjust the tool slide until it is exactly perpendicular to the straight-edge by the scratched

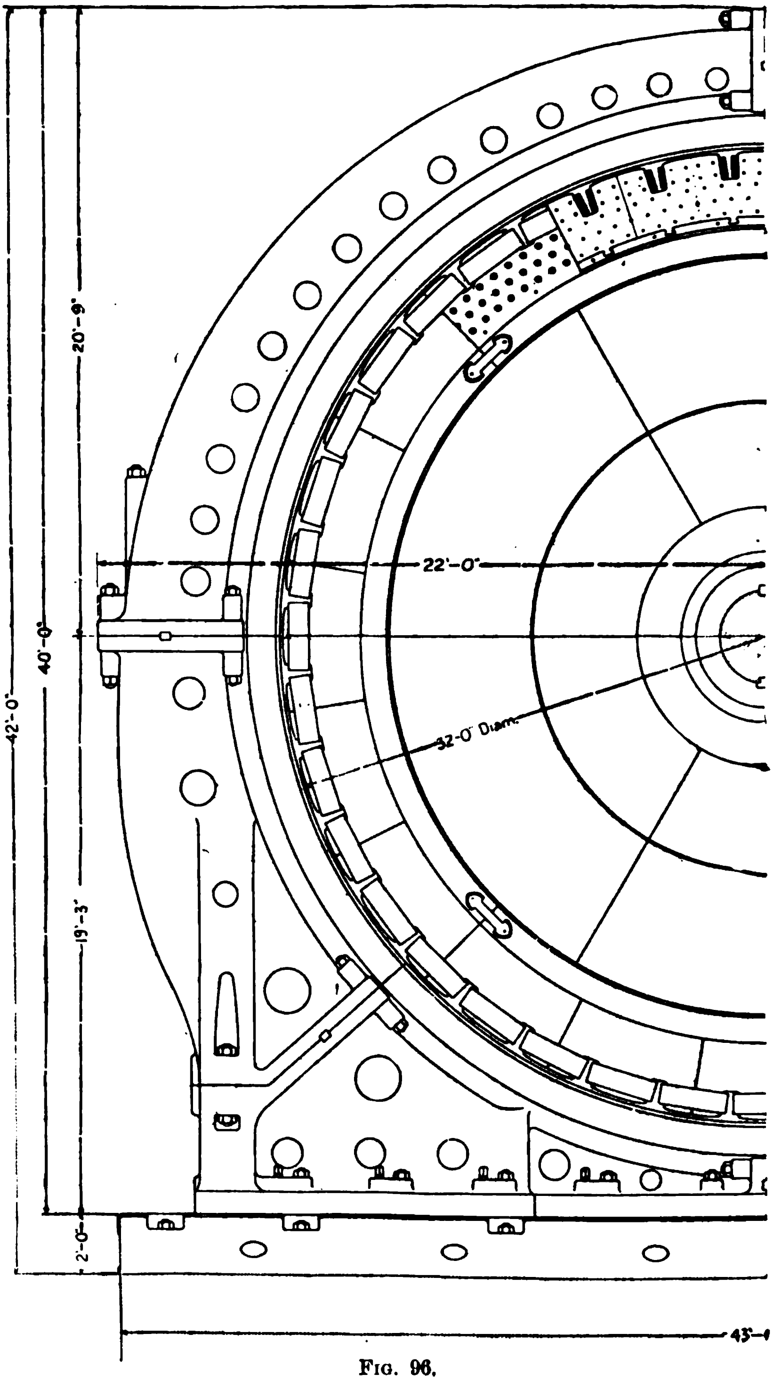


FIG. 96.

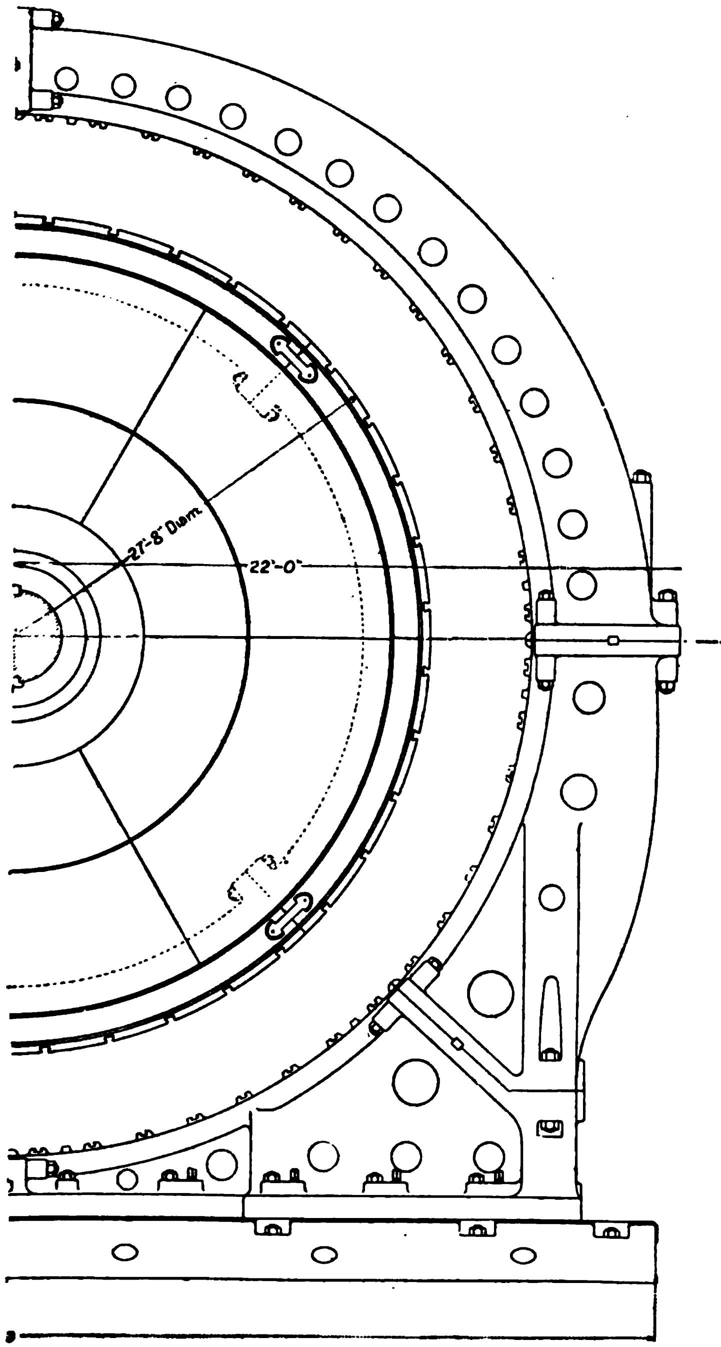


FIG. 97.

line as determined by the telescope. A transverse movement of the tool slide to its near and far position will indicate any error; if one be found, it is best to correct the machine by planing or scraping, as may be necessary.

12. To test the spindle travel of a portable horizontal drilling machine, set the instrument to cut the line of a target attached to the end of the spindle, and survey the spindle in its different horizontal positions. The vertical travel of the spindle slide can be determined by locking the spindle in one position and moving the slide up and down, the same as for testing the slotter. Other portable machines can be tested by similar means, and the result of the tests can be depended upon if the instrument is accurately made and the errors in the subdivisions of the circle are known.

Practical Application of the Method.

13. The method described has been practically applied to some of the mechanical operations incident to the manufacture of the eight 5,000 kilowatt, alternating current, engine type, 3-phase generators built for the Manhattan Railway Company by the Westinghouse Electric and Manufacturing Company.

The approximate dimensions of some of the principal pieces of one of these generators are shown in Figs. 96, 97, and 98. The extreme height from the bottom of the bed to the top of the yoke is 42 feet, and the greatest horizontal distance over all is 44 feet. The bed plate, 43 feet long, has two parts, securely keyed and bolted together, each 21 feet 6 inches long by 10 feet 3 inches wide by 2 feet thick.

The stationary element, or armature, has six principal sections—two lower, two middle, and two upper—all securely keyed and bolted together; the bore being 34 feet, approximately.

The revolving element, or field, consists of many pieces, the principal ones being the cast-steel hub, the two web plates of six pieces each, and the four ring sections. The diameter of this element is 27 feet 8 inches over rim sections, and 32 feet over all.

The total weight of the stationary and revolving elements of this machine (without the shaft) exceeds 1,000,000 pounds, or 500 tons.

14. After the preliminary design of these machines had been determined upon, it was apparent that the buildings, travelling cranes, and machine tool equipment then in service at East Pitts-

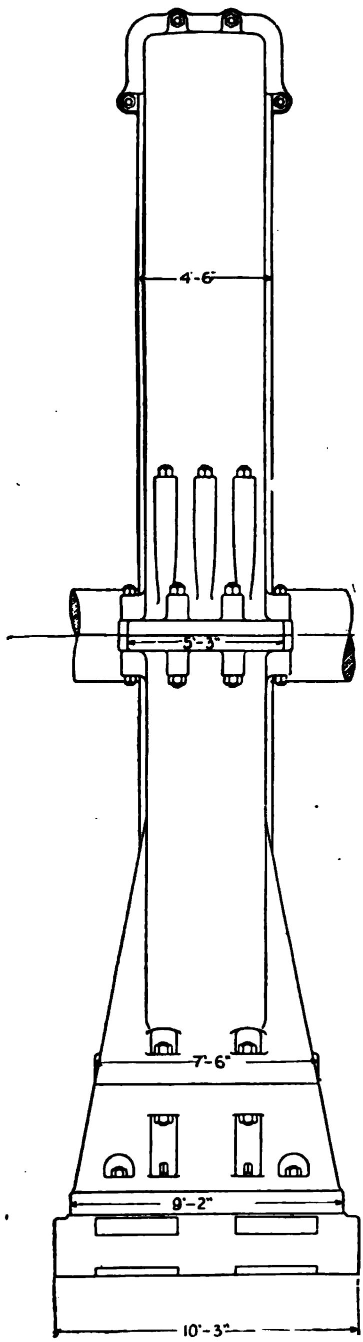


FIG. 98.

burg were inadequate for the work. A new building was therefore erected, and electric travelling cranes were provided, having ample capacity and mounted on runways of sufficient height to give the crane-bridge the necessary clearance over the top of the generators. It was also apparent, after carefully studying the design, that some of the machining operations could best be performed by the use of portable machine tools, while for others stationary machine tools would do the work more advantageously.

15. For the operations to be performed by portable tools, and for the erection of the machines, a surface floor plate was considered a necessity, and the one provided is 48 feet wide by 176 feet long; weight, about 2,000,000 pounds. This floor plate consists of 132 cast-iron sections, each 8 feet square, of box section heavily ribbed, keyed, and bolted together—provision being made for the removal of any broken section, should such a mishap occur. The plate, well grouted, rests upon transverse brick piers 12 feet deep built upon a solid bed of concrete, about 3 feet 6 inches thick. The brick piers are 4 feet apart, centre to centre, tied together at suitable distances by brick arches, and the space between the piers is filled in to within 5 feet of the under side of the cast-iron plates. The filling between the piers is covered by a layer of concrete, having enough pitch to properly drain into a longitudinal tunnel at one side of the plate. There are numerous rows of drilled and reamed holes for stop lugs, and tee slots extend the whole length of the floor plate, with numerous cored holes at the bottom of the slots to permit the chips to fall through into the transverse tunnels. The longitudinal tunnel has numerous trap doors through which the chips can be taken out, and by a suitable sewer connection it is possible to thoroughly clean, wash, and drain this tunnel whenever necessary.

16. The principal portable machine tools used were vertical slotters or planers having a stroke of 8 feet, a small horizontal adjustment of the tool slide, a transverse tool travel of 4 feet—the column having a horizontal adjustment of 4 feet; horizontal drilling machines having a vertical adjustment of 8 feet, the column a horizontal adjustment of 4 feet, with spindle travel of 4 feet; vertical slot milling machines, radial drills, and small vertical slotters.

The principal stationary machine tools were a 14-foot planer, 8-foot open-side planer, radial drills with 10-foot arm, 16 to 24-foot and 16 to 36-foot extension vertical boring and turning mills, 28-

foot vertical boring and turning mill, 122-inch engine lathe, a special floor-boring machine carrying portable heads, and several smaller machines.

THE STATIONARY ELEMENT.

Bed Plates.

17. The bottom and top of bed plates were planed on the 14-foot planer; the joint surface and keyway on the open-side planer, and the joint bolt holes were drilled on the floor plate with portable horizontal drilling machines.

Bottom Sections.

18. The bottom sections were the most difficult to machine, and a more detailed description of some of the operations on these pieces will make it unnecessary to outline so fully the operations on the other sections.

By referring to Fig. 96, it will be noticed that the lower or perpendicular joint is at right angles to, and the upper joint has a portion parallel to, the bottom or base—the remainder of the upper joint being at a definite angle from the lower joint. The rough casting was mounted on the floor plate, resting on cast-iron blocks, the bottom being set approximately perpendicular to the plate, as shown in Fig. 99.

19. The proper location of the section involved the making of numerous measurements to insure plenty of stock for finishing—this being particularly necessary for the slot lugs located in the bore. The centre column was mounted on the floor plate and its position determined by the centering gauge, as shown in Fig. 99—more or less proof testing being necessary to insure its exact location, after which it was securely clamped to the plate.

The perpendicularity of the faces of the slot lugs was determined by scribing lines upon the top surface of the slot lugs with the centre gauge at the proper elevation, and by lowering the centre gauge rest or support similar lines were scribed on the bottom surfaces of the slot lugs—scale measurements being accurate enough to prove this setting, after which the bottom section was bolted to the floor plate. The dividing instrument was then mounted upon the column, properly levelled, and finish lines scribed at each joint surface.

Straight-edges were then secured to the floor plate in their exact

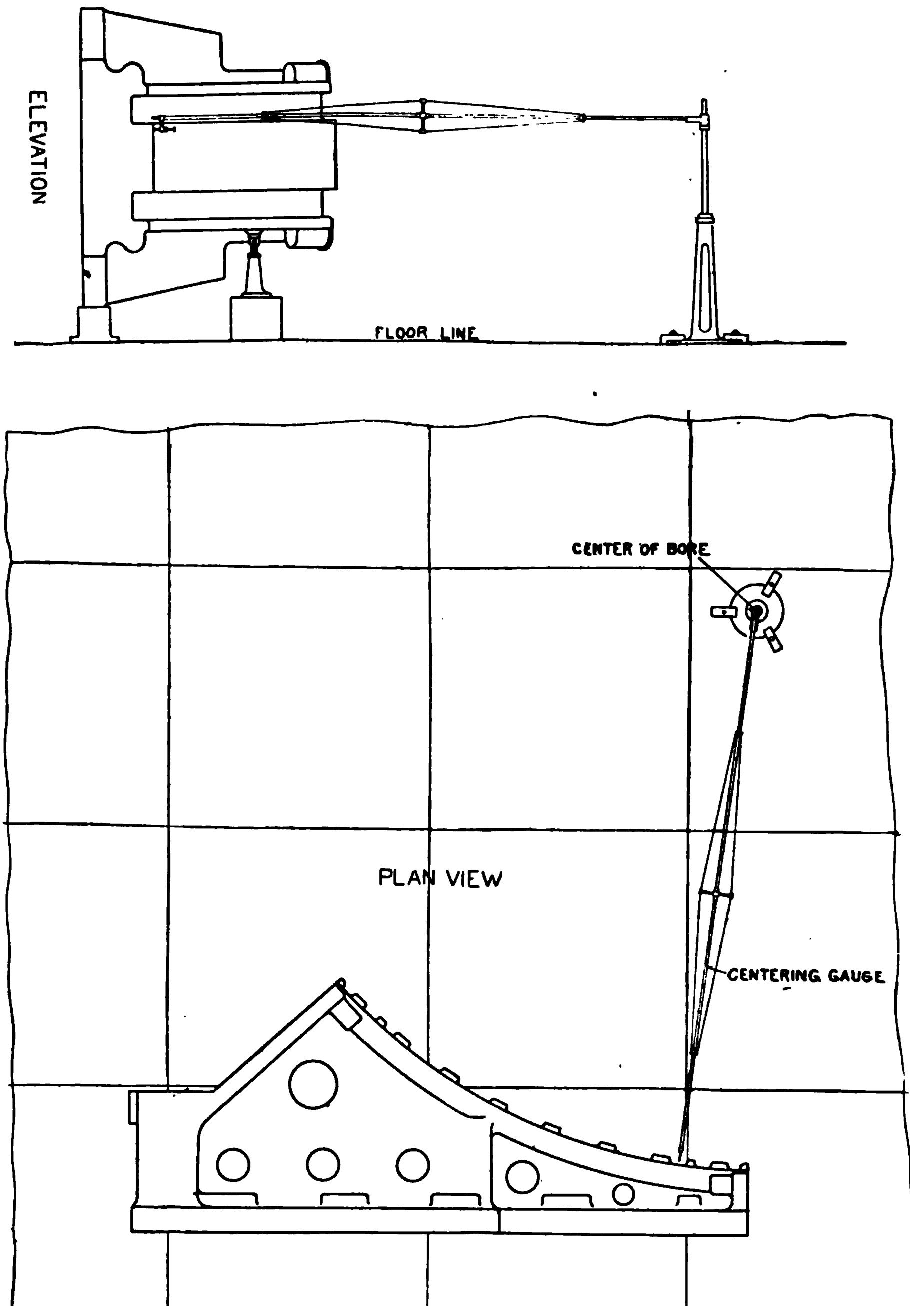

ELEVATION
FLOOR LINE
CENTER OF BORE
PLAN VIEW
CENTERING GAUGE

FIG. 99.

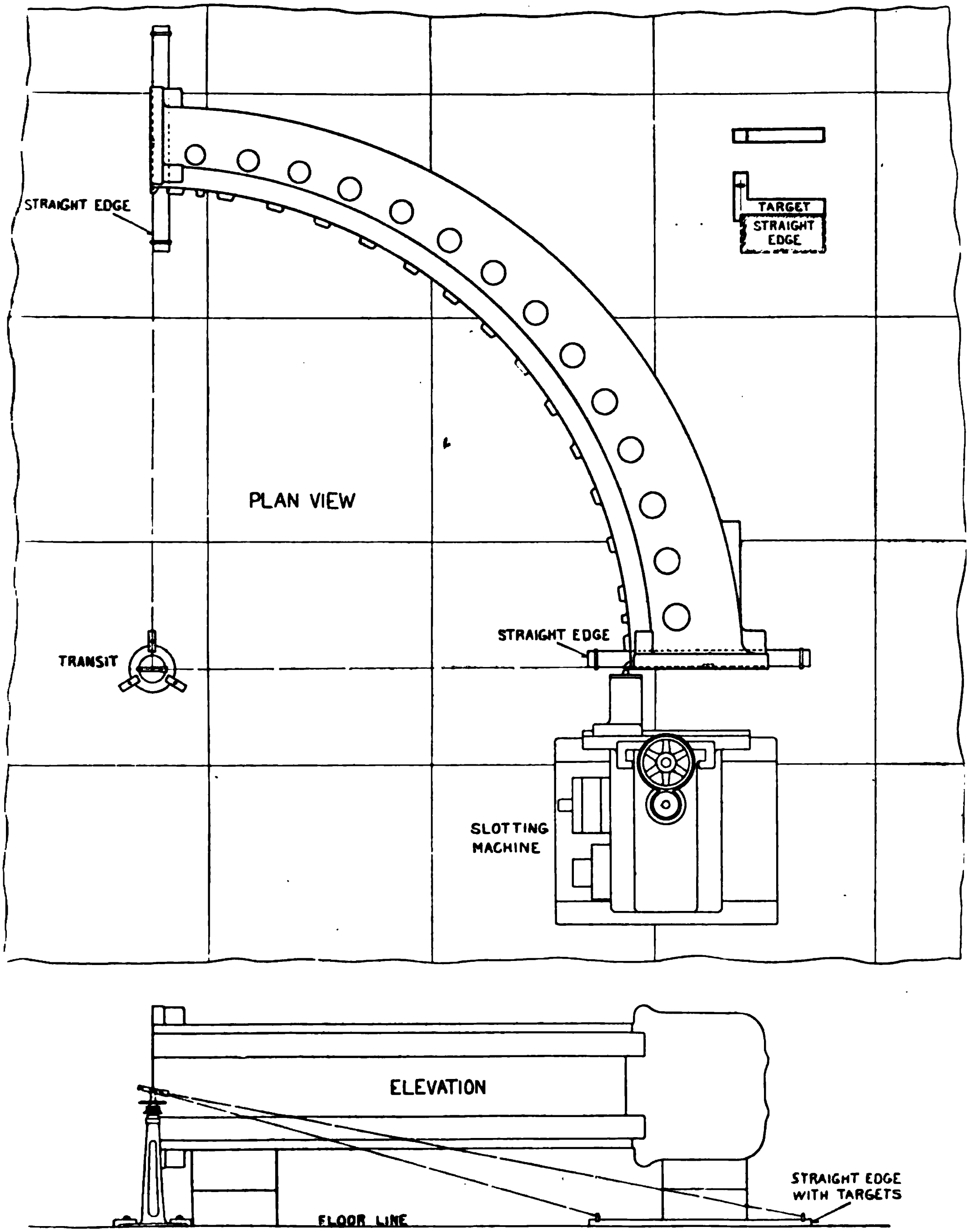

STRAIGHT EDGE
TARGET
STRAIGHT EDGE
PLAN VIEW
TRANSIT
STRAIGHT EDGE
SLOTTING MACHINE
ELEVATION
STRAIGHT EDGE WITH TARGETS
FLOOR LINE

FIG. 100.

position—one edge of each being set exactly perpendicular to the desired finished joint surface, the position of these straight-edges being determined by the dividing instrument and suitable target, as shown in Figs. 100, 101, and 104.

20. After proving the exact position of these straight-edges, the portable slotters were set in their correct location, secured to the

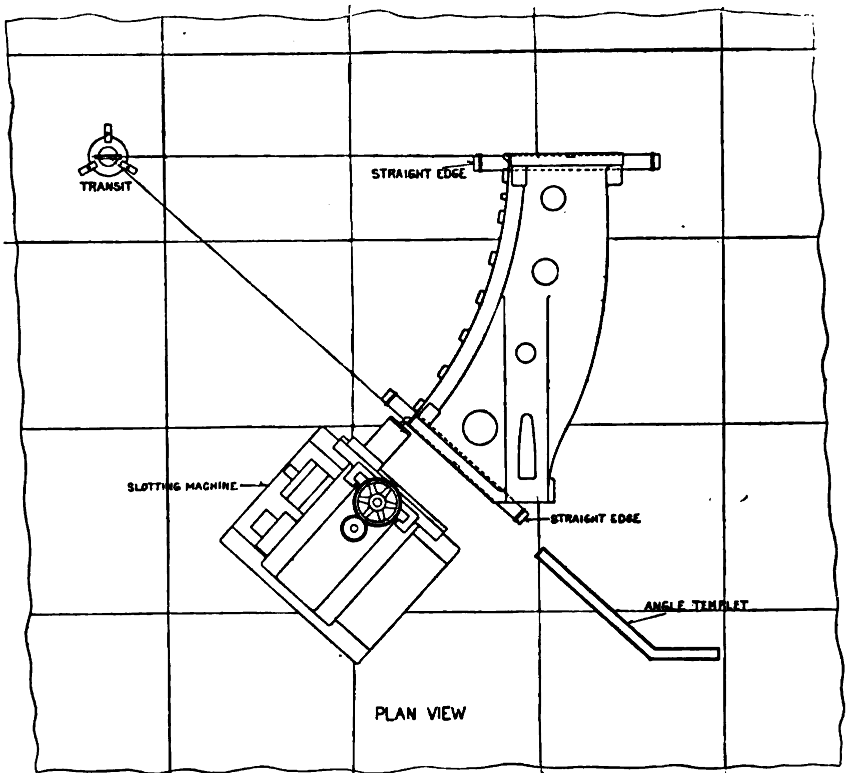


FIG. 101.

plate, and the roughing cuts taken—slotters often working upon both joints at the same time. The accuracy of the rough planed joint surfaces was proved by the dividing instrument and an adjustable target, after which the cutting tool was set by the instrument for the final radial finishing cut. For that portion of the upper joint of this section parallel to the bottom, the slotter was set by the aid of the angle template, shown in Fig. 101—a pin gauge proving that the tool slide was parallel with the angle template.

The joint bolt holes were drilled by the portable drills shown in Fig. 102, the position of the bolt holes being determined by the use of drill jigs located by keys and by a centre line. The drill jigs were made reversible for drilling holes in the faces of the corresponding joint surfaces of the connection sections.

After completing the operations upon the joint surfaces, the lower sections were finished upon the bottom on a stationary planer. The next operation was the drilling of the bolt holes and

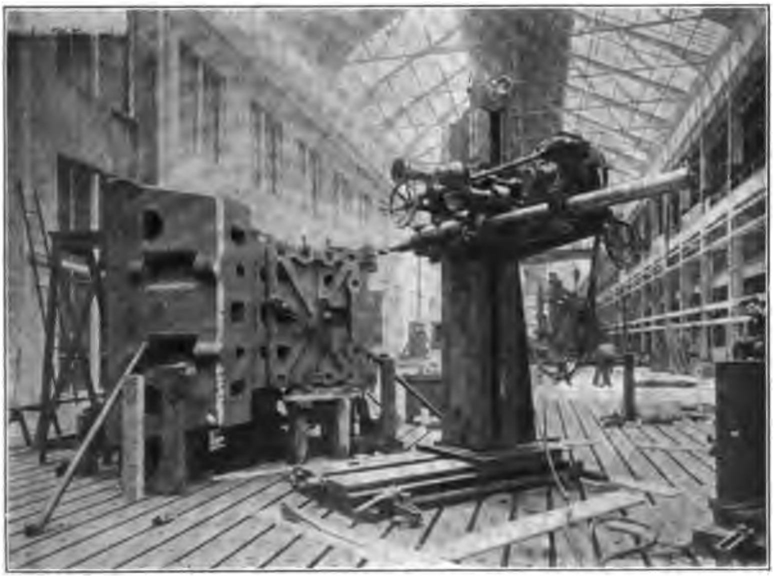


FIG. 102.

the drilling and tapping of the adjusting screw holes in the bottom of the section under radial drills.

Middle and Upper Sections.

21. The operations upon the joint surfaces of the middle and upper sections were laid out and finished in substantially the same manner as were those on the lower section; some of them being shown in Figs. 100, 101, 103, and 104.

First Assembling of the Stationary Element.

22. After finishing all the principal operations upon the joints of the six sections, the two lower sections were placed in position

on the floor plate and the lower joint bolted together. The two middle sections were next placed in position and securely bolted to the lower sections. After assembling the two lower and two middle sections of the first generator, it was thought advisable to survey the surfaces of the upper joint of the middle sections to be sure that they were level and in exact alignment with the centre of the machine. These surfaces were found to be so accurate that surveys of the same were not considered necessary on succeeding generators.

One of the upper sections was next placed in position and securely bolted to one of the middle sections. As the joints of the upper section were planed at an angle of 90 degrees, and as the bore was 34 feet, the distance from the inner edge of the horizontal joint to the centre was 17 feet. If there were not any deflection the vertical joint would have been exactly in alignment with the vertical joint of the lower section, but it was found that the upper joint over-hung six-hundredths inch in the first generator, and the over-hang in the succeeding seven generators in no case exceeded eleven-hundredths inch. The total variation between the generators, therefore, was five-hundredths inch. The amount of overhang was determined by the use of a plumb line—the elevation of the surveying instrument not being sufficient to permit its use.

23. The second upper section was next placed in position and first securely bolted to the middle section. After this was done an examination of the upper joint was made, and it was found that a very thin piece of sheet steel could be inserted at the lower edge of the joint, while it was tight at the upper edge. When the bolts were put in place and well tightened the joint was absolutely tight all over, and tests with the plumb line showed the joint to be exactly in alignment with the vertical joint of the lower sections. The variation in the alignment of the vertical joints of eight generators did not exceed three-hundredths inch.

Careful measurements of the vertical diameter were made before the second upper section was put in position, and in every case but two it was found, after placing the second upper section in position, that the tightening of the bolts of the upper vertical joint actually increased the vertical diameter by an appreciable amount, although not exceeding five-hundredths inch in any instance. This result seemed to prove quite conclusively that no errors had been made in laying out the work or in planing the joint surfaces. It also proved to those responsible for the work

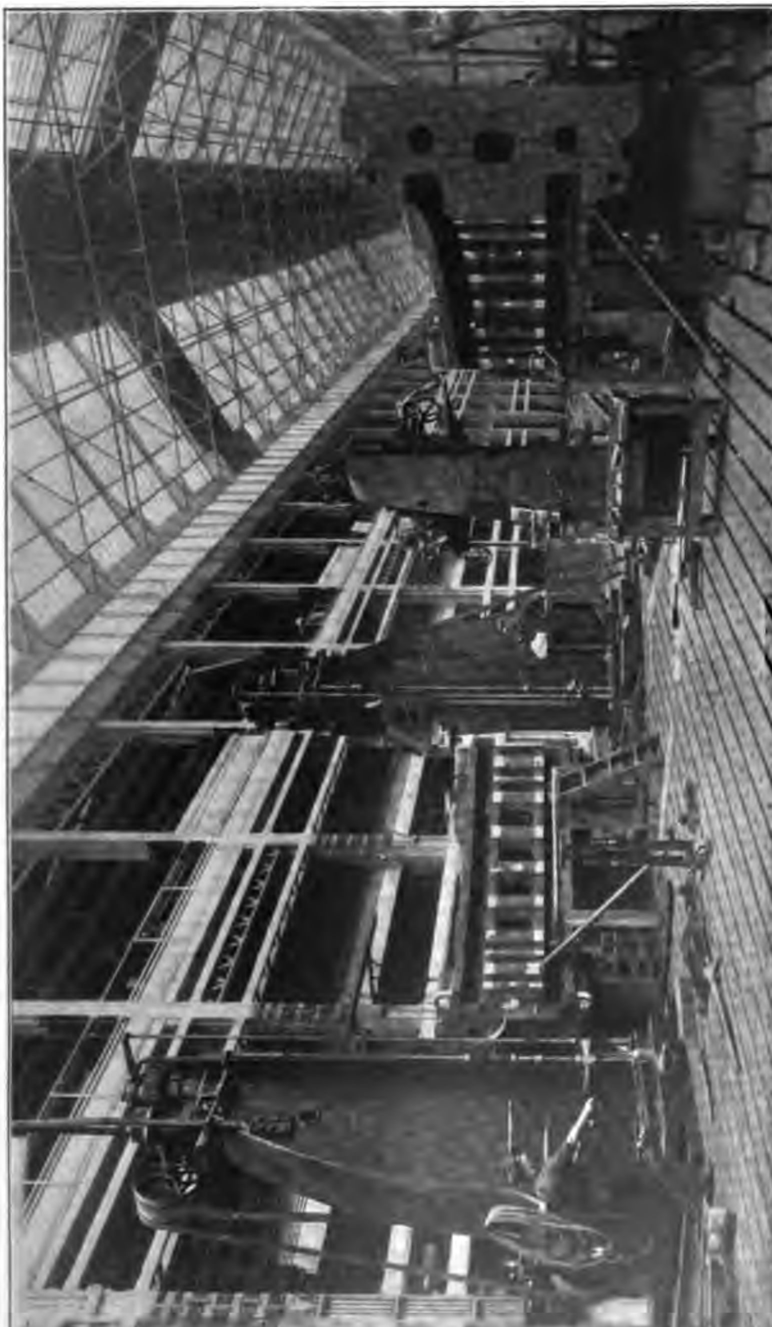


FIG. 163.

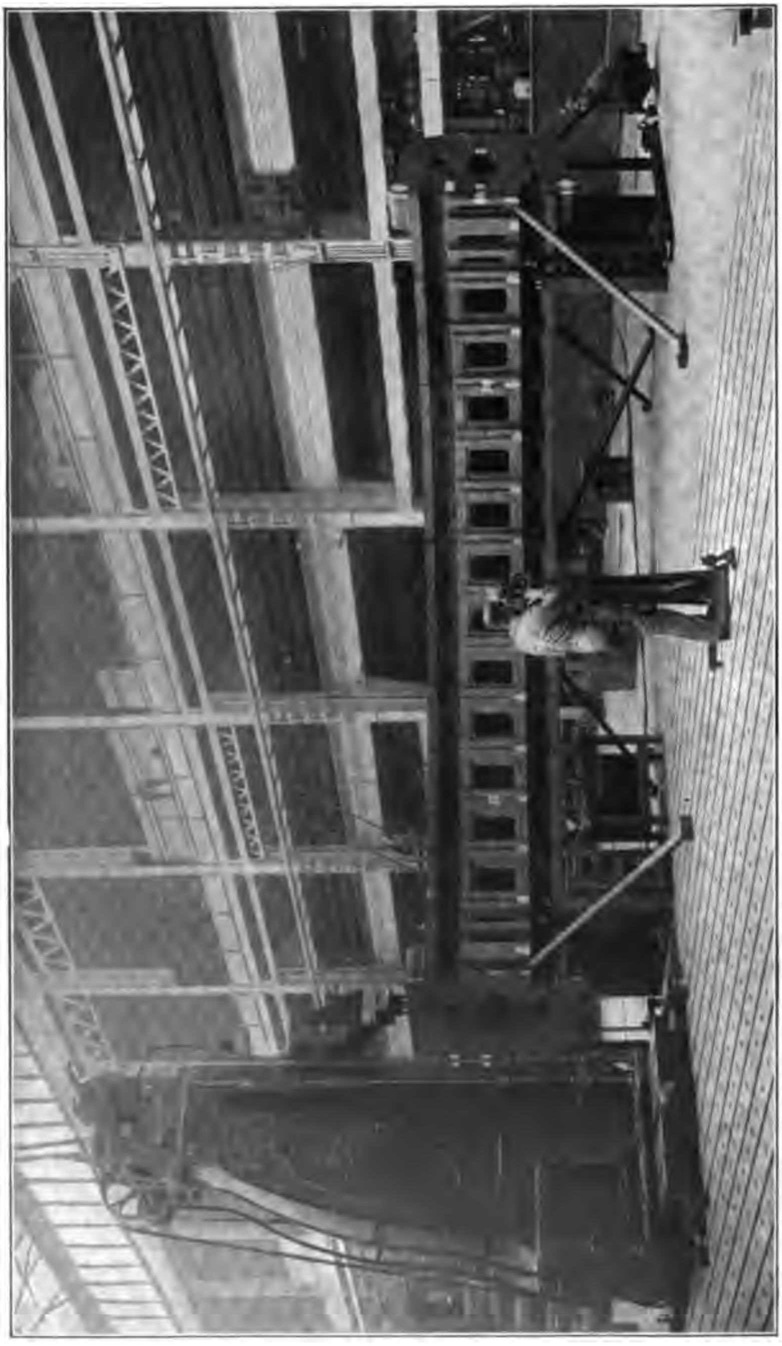


Fig. 104.

that the method was practical, and that the dividing instrument could be relied upon for accurate results. After assembling the six sections and making proof measurements, the work of chipping the edges of the joints, broaching the sides of the keyways, and fitting the keys was performed. Careful measurements of the horizontal and vertical diameters were recorded, and then the frame was taken apart.

Second Assembling of the Stationary Element.

24. The six sections were next assembled on the special floor-boring machine—the axis of the bore being in a vertical position (see Fig. 105). This boring machine is 48 feet square and has a rotating table over 18 feet diameter, carrying various portable tool heads, which, for large work, are supported on arms having sufficient radial adjustment to bore up to 40 feet diameter. The driving mechanism is entirely under the floor, with operating levers at the side of the machine. Current for driving the motors operating the feed mechanism of the portable tool heads is carried up through the centre of the rotating table, where connection can be made by flexible cables.

The assembling of the six sections followed in the order of the first assembling. The lower sections were positioned by a heavy angle-plate securely fastened to the boring machine, which determined the exact distance from the centre to the bottom of the generator. After the sections were properly blocked and bolted together, careful measurements were made of what were the vertical and horizontal diameters when the sections were first assembled. In each case it was found that the former vertical diameter had increased twelve-hundredths inch and that the horizontal diameter had not changed materially, showing that most of the deflection was in the upper section. By numerous heavy braces and taper wedges the upper sections were sprung toward the centre until the diameter corresponded with the diameter recorded during the first assembling. The frames were then bored, faced, and recessed to the required dimensions. The dove-tailed slots for holding the sheet steel laminations were planed and milled—the spacing of these slots being determined by the table of the boring machine.

25. The table was graduated as follows: In the edge of the table there were 360 holes drilled one-quarter-inch diameter, into which were driven brass plugs. The edge of the table was slightly re-

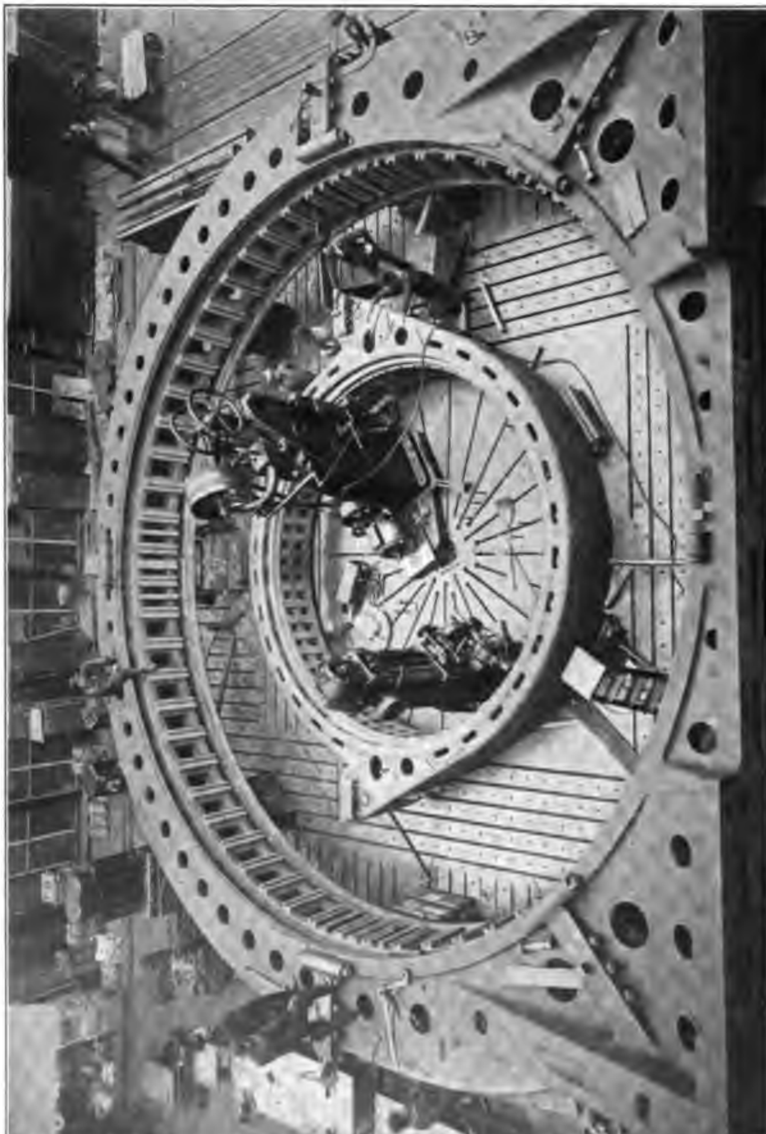


FIG. 105.

cessed and the brass plugs faced to protect them from injury. The dividing and levelling instrument was mounted upon a column accurately fitting into a recess in the centre of the table, and a target was set up at quite a distance away. The subdivisions of the circle were obtained by rotating the table until the cross line of the telescope exactly cut the line on the target for each degree —the line then being made on the brass plug by a special graduating fixture attached to the bed of the machine.

After the operations were all performed on the frame the six sections were taken apart. The sheet-steel laminations, ventilating plates, end plates, and clamping bolts were next assembled with each section of the stationary element.

End Plates for Stationary Element.

26. The end plates for clamping the sheet-steel laminations were made from steel castings and were 35 feet 4 inches outside diameter with 16 inches face. These plates were turned on a 36-foot extension vertical mill. The end plates were carried on plates mounted upon twelve outriggers bolted to the 14-foot table of the mill. To these outriggers were attached adjustable shoes resting on an annular bearing 29 feet diameter, which gave sufficient support to the outriggers and relieved the table of undue strain. The driving mechanism for this mill was the same as in a 16 to 24-foot extension mill and was not of sufficient strength to permit of taking heavy cuts.

27. A worm-gear drive was recently provided having somewhat unusual sizes. The cast-iron worm gear has 180 teeth made in 12 sections having 15 teeth each; pitch diameter, 33 feet 5 inches; face, 13½ inches. The twelve sections are securely bolted together and bolted to the outriggers. The worm is of cast iron, 20 inches diameter, 20 inches long, 7 inches pitch, single thread of involute rack tooth form, 30 degrees included angle. The worm is driven by suitable gearing and runs 30 to 63 revolutions per minute, driving the table one turn in 8¾, 6, 4, and 3 minutes; cutting speeds, at 36 feet diameter, 13, 19, 28, and 37 feet per minute.

The Revolving Element.

28. The dividing and levelling instrument was used only on the rim-section joints and to subdivide the circle for the dove-tailed slots. The joints were made by the same means as used for the

stationary element sections. The operation of subdividing the circle is shown in Fig. 106, in which the instrument is mounted on a centre column and the lines are ruled on brass plugs by a special graduating device.

The Dividing and Levelling Instrument.

29. The instrument in daily use at East Pittsburgh was designed and made by The Warner and Swasey Company, of Cleveland,

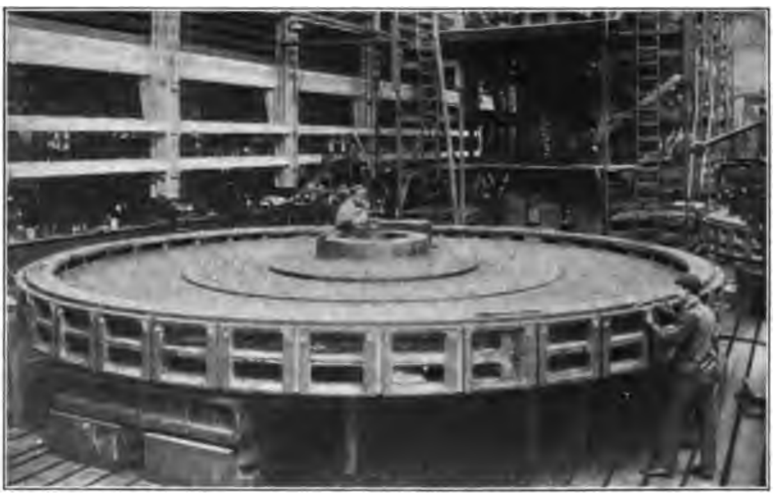


FIG. 106.

Ohio, who kindly furnished the writer with the following description:

"The knurled base on which the instrument rests is provided with an internal thread for screwing it to the cap of a tripod; or, if it is preferred, a supplementary base can be screwed to it, the latter being provided with a taper hole for readily centering the instrument on a suitably designed cast-iron column. The knurled base has four levelling screws, by which the body of the instrument is attached, the usual supporting ball and socket joint being provided in the centre between the two.

"In the centre of the instrument are two vertical spindles, the one fitting inside the other. The outer spindle carries the horizontal circle independently from the inner spindle, which carries the supporting yoke and the telescope. The circle is provided with clamps and slow motions so that its 0 division can be brought to any position in azimuth, and there clamped independently of the telescope. The circle is 12 inches outside diameter, and is provided with an inlaid silver strip or band one-quarter inch wide

FIG. 107.

divided into one-sixth degrees, which are read by vernier and reading microscope to ten seconds. The circle also has a second series of graduations, which are read by two opposite microscopes, with a magnifying power of twenty-four, direct to one-tenth degree.

30. "The yoke is mounted on the inner spindle and is provided with clamps and slow motions, so that the telescope can be moved to any azimuth position relative to the circle and independently of it. It has two 2-minute horizontal levels, 90 degrees apart, for quickly setting the instrument. The telescope rests in a cradle so arranged that it can be revolved about its long or optical axis, the cradle resting in Y bearings which are reversible for collimation, the line of collimation being perfect from a distance of 10 feet to infinity.

"The telescope has an objective one and one-half inches in diameter, a focal length of eleven inches, and gives, with two eye-pieces, magnification of 15 and 22, respectively. The eye-piece has the usual cross wires and focusing adjustment with rack and pinion.

"The cradle trunnion carries a slow-motion arm, which can be clamped at any position for accurate altitude setting. The striding level is seven and one-half inches long, has an air chamber and divided scale, one-tenth-inch bubble travel being equivalent to 10 seconds of arc."

31. Mr. Swasey has stated to the writer that the greatest error in the subdivisions of the circle of this instrument would not exceed one second of arc—an amount equal to 0.3072 inch at a distance of one mile.

So many uses have been found for the instrument, and it has proved so valuable, that a second one was recently ordered to be on hand in case of accidental injury to the one now in service.

DISCUSSION.

Mr. George L. Fowler.—This method of using a surveying instrument in a machine shop can be applied in almost every one's practice in a number of little things. I found a transit about the handiest thing that I could lay my hands on for lining up and levelling shafting. One can stand on the floor with the instrument in a fixed position and get a line of shafting running down through a long shop perfectly straight and very much more nearly a true level than is possible with the ordinary methods of a string measurement and the ordinary level which is used by millwrights. I found, too, that where I have had a long line of separate pieces of counter-shafting that I wanted to get in line with the main shaft, that by simply taking an offset with the transit and keeping that in line, I could bring all of the counter-shafting in parallel with the main line and make it level at different heights, and do that work in less than half the time that would be required to put up shafting in the ordinary way. I also used it for leveling engine beds and large pieces of machinery in the same way. A level or transit once accurately fixed is worth a great deal more than the ordinary spirit level.

Mr. Fred J. Miller.—About twenty years ago I had some similar experience in lining up some long lines of shafting with a transit, which was also a theodolite, so arranged that the telescope rested in Y bearings, and could be reversed; it had a good level upon it. There were several long lines of shafting, and they had been lined up every year when the factory shut down. They did it in the old way with carpenters' levels, and every year it seemed to be necessary to alter the levels of those bearings. The level indicated that they needed alteration. At the time I speak of, we tried the transit and leveled the line shaft with it, using the good level that was on that instrument. The next year they supposed it was necessary to line the shafting again as usual, but when they came to put the transit on the second year the shaft did not need any lining up; that simply indicated that we had with the transit really lined it for the first time and that it stayed in position. It also showed that which I think is generally the case—*i.e.*, that in the shop it is not generally appreciated what a really faulty instrument of precision the ordinary level is. It is nowhere near precise. It won't show "within a row of apple trees" whether you are level or not, but a good level such as is put on an engineer's instrument will really show you whether a line is level or not.

Mr. F. H. Boyer.—About eight years ago I laid out a new device in abattoir work for the handling of slaughtered hogs, where the men were working nearly as close as we are in this room. It consisted of shafting, pulleys, an overhead railroad, and a great many different devices. While the men were proceeding with the slaughtering on the floor, the work was laid out with a transit, and when it was started up there was not a hitch of any sort.

Mr. P. A. Sanguinetti.—The members have spoken a great deal about the use of a leveling instrument for leveling shafting. It might be of interest to some of them to know that there was a case where a leveling instrument was used, not to level a shafting, but to insure its being straight when out of level. I refer to the machinery hall in the Centennial Exposition in Philadelphia. The ground was something like two feet out of level, and the engineers, to save expense, made the building to suit the slope, and the shafting had to be parallel with the floor. A surveying instrument was used there to great advantage. The proper angle was calculated, and the ordinates set up by sighting. I do not suppose many of the younger members would know of such an instance where a leveling instrument was used to set up a shaft out of level.

*Mr. C. C. Tyler.**—I am well aware of the fact that the surveyor's transit and level have been used for a number of years for the leveling of shafting, planer beds and engines, but I had not heard of using a dividing and leveling instrument for laying out large work, or for setting and proving portable machine tools, before I decided upon its use for the work described in this paper. It was the use of the instrument as applied to setting portable tools to insure their being exactly perpendicular to the surface floor plate, and in the correct position to obtain exact angles when machining the joints of large machines, that I thought might prove of interest to the members. New uses for the instrument are often found, new ways of locating tools which insure very accurate work, and it has proved of particular advantage in making subdivisions of the circle. You will note on the last page of the paper its circular divisions have an almost inappreciable error, about three-tenths of an inch to the mile, and when carefully used the finished work on large machines should be sufficiently accurate for practical requirements.

---

* Author's closure, under the Rules.

No. 970.*

ROTARY PUMPS.

BY JOHN T. WILKIN, CONNERSVILLE, IND.
(Member of the Society.)

1. The writer has been searching diligently for the past sixteen years for information about rotary pumps, in order to have the benefit of the experience of others. The greatest amount of information was found in the United States Patent Office Records, and in Professor Reuleaux's "Kinematics of Machinery," translated and edited by A. B. W. Kennedy, C.E., and published in 1876 by MacMillan & Co., London—a book which has been out of print for some time and is very difficult to obtain. In this work Professor Reuleaux cites records of the use of this pump as early as 1630, the pumps described having two impellers, each of which had four lobes or teeth; and he shows and discusses many forms of rotary positive machines, some of which were intended for steam engines, some for pumps, and other for blowers. This book contains the most comprehensive history and discussion of rotary machines that the writer has been able to obtain.

2. The development and commercial use of rotary pumps kept pace with the other types until about thirty or forty years ago, when they became quite unpopular, largely due to the fact that they were misapplied, and because the manufacturers undertook to produce them too cheaply in order to compete with centrifugal pumps, making the contact surfaces of the impellers unfinished castings. The misapplication was in using small capacity machines for high pressures, resulting in a large per cent. of leakage and developing weakness of construction.

3. The writer, after a careful study and analysis of the different forms shown in the above-mentioned records, and also those which were on the market at that time, decided, about ten years ago,

* Presented at the New York meeting (December, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions.*

that a rotary pump having two similar impellers, the contours of which were formed by complete epi- and hypo-cycloids, would make a machine which would give excellent results if properly constructed and applied. Fig. 108 shows a cross section of such a pump, which is designated as a two-lobe cycloidal pump, and it is this form which will be principally discussed in this paper.

4. The writer has proceeded with the belief that a rotary pump is a good device for moving large volumes of fluids at low or moderate pressures, and has avoided using them on high-pressure work. This form was selected for the following reasons, viz.:

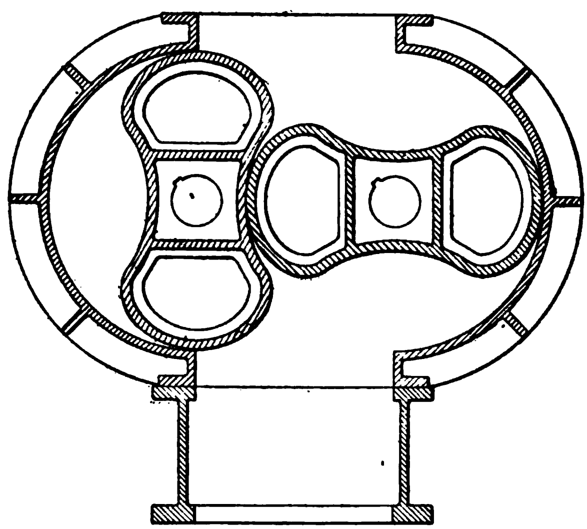


FIG. 108.

The outlines of the impellers are mathematically correct, hence the clearance can be made uniform.

The shape admits of a strong casting in a single piece, thus avoiding internal fastenings or joints.

The impellers revolve freely in their cylinders, hence there is no internal friction, packing, nor necessity for lubrication.

The minor axis of the impeller is large enough to permit the use of a shaft of ample diameter, leaving sufficient metal for a good hub, and at the same time giving a relatively high capacity to a machine having a given distance between the shaft centres.

There is no sudden change of work on these impellers nor in the pump as a whole.

There is no tendency to form enclosed pockets between the impellers in which the fluid would be compressed, causing unnecessary work.

5. It is a remarkable fact that all of the principal rotary pumps on the market at that time were so arranged that there were two or more points of contact between the impellers in certain portions of the revolution, thus forming compression spaces, the same as in the case of a pair of gears used as a pump. This reduction of volumes when the pump is used for liquids is very destructive in its effect, and was recognized by certain designers, who provided grooves in the end plates connecting these spaces with the suction side of the pump, thus relieving to some extent the shock.

The displacement per revolution of a two-lobe cycloidal pump is exactly the volume of the cylinder in which the impeller revolves; or, in other words, the area of a two-lobe cycloidal impeller is one-half the area of the circumscribed circle. This fact makes it possible for this form to be used as a meter, the displacement of which can be very accurately determined.

6. The discharge from the pump is continuous but not uniform. One of the errors which has been committed in connection with rotary pumps is that their manufacturers have claimed the discharge to be uniform. Figs. 109 and 110 show diagrams of the path of contact between the two impellers, and the variation of work on each one, also the variation of the combined work of both. The base line in Fig. 110 is a development of the pitch circle, the radius of which in this case is 2 inches. If the length of the impellers be assumed as unity, the capacity of the pump per revolution is represented by the area enclosed between the base line and the line 2¼ inches above. The dotted curved line in Fig. 110 represents the variation of work of the impeller shown in dotted lines in Fig. 109, while the lower full-curved line in Fig. 110 represents the work of the opposite impeller. The upper curve represents the combined work of both impellers. The distance between the ordinates represents the travel at the pitch line, also the travel of the point of contact in the circumference of the small generating circles. This diagram was made to determine the amount of water which must be absorbed and given off by the air chambers when the pump is used on liquids and the areas between the upper curved line and the line of mean discharge enable us to determine this quantity. It will be noticed that the point of maximum discharge is ten-ninths and the point of minimum discharge is eight-ninths

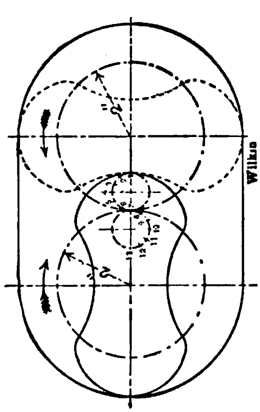


FIG. 109.

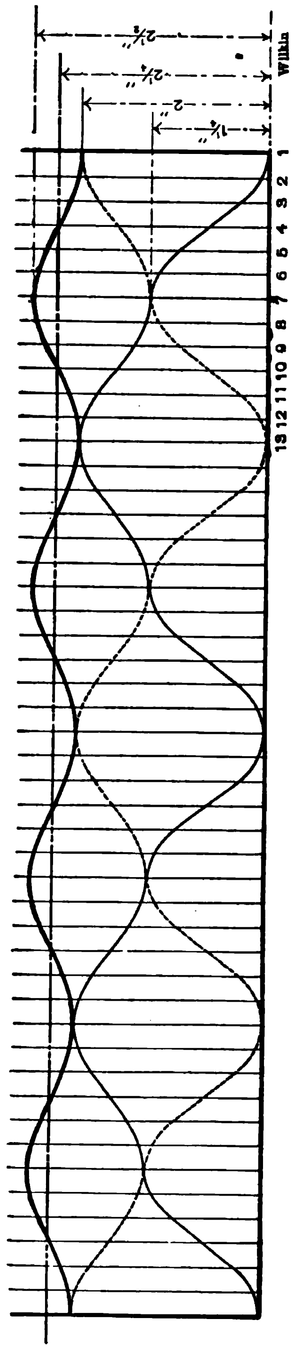


FIG. 110.

of the mean discharge. The work on each impeller varies from zero to a maximum shown 2 inches above the base line. The minimum work of the pump occurs when the impellers are at right angles to each other, as in this position one impeller is balanced and the opposite one is at its point of maximum work. The position of maximum combined work of the two impellers is when their major axes are parallel to each other and at angles of forty-five degrees to the line of centres.

7. Assuming one of the shafts to be the driver, the work transmitted by the gears varies with the work of the driven impeller. The maximum gear transmission, therefore, is eight-ninths of the mean work of the pump.

The area which each impeller presents to the working pressure is variable, as is also the direction of the resultant pressure, the maximum area of the impeller being exposed to the full difference of pressure, under which the machine is working, when the major axis of the impeller is parallel to the line of shaft centres. The points of contact with the cylinder and with the other impeller are on the centre line at this point, and the impeller is in a balanced position doing no effective work, so that in this position the total load due to the pressure, plus the weight of the moving parts, is downward or at right angles to the line of centres. As the impeller leaves this position the direction of pressure and the exposed area vary until the impeller reaches a position at right angles to the line of centres, where it has its maximum unbalanced area exposed, and also where it undergoes a change in direction of pressure, due to the passing from suction to the discharge, of the inclosed volume of fluid between it and the cylinder.

8. In designing rotary pumps one of the principal problems to be solved is the proper provision for supporting the impellers. They are supported by their shafts resting in journal bearings separated from the cylinders by stuffing boxes; hence, the problem is a modification of the beam supported at the ends and carrying a load varying in intensity and direction, the load being distributed over a portion of its length. This problem can hardly be solved by any other method than experience, but when properly solved the rotary pump has proven itself to be an excellent device for moving large volumes of fluids against moderate pressures. The designer of rotary pumps is not compelled to consider a multiplicity of valves, ports, etc., such as is met with in the design of reciprocating machinery, nor does he have the problem of veloc-

ities, centrifugal force, fluid friction, accurate balancing, etc., as encountered in designing centrifugal machines.

We have up to this time used the word pump in its broader sense, but in considering the uses of rotary pumps the machines used for elastic fluids should be discussed apart from those used for liquids. The action of a rotary pump or blower as an air compressor is practically the same as the action of a duplex, crank-and-fly-wheel, double-acting, piston compressor which has mechanically operated valves opening and closing at the beginning and end of the stroke, assuming the piston machine to have no clearance spaces. There is, therefore, no gradual compressing of air in a rotary machine, and the unbalanced areas of the impellers are working against the full difference of pressure at all times. The possible efficiency of such a machine under ordinary temperature and conditions of atmosphere, assuming no mechanical friction, leakage, nor radiation of heat of compression, would be as follows:

Compression to	one	pound	gauge	pressure	$97\frac{1}{2}$	per cent.
" "	two	"	"	"	$95\frac{1}{4}$	"
" "	three	"	"	"	$93\frac{3}{10}$	"
" "	four	"	"	"	$91\frac{7}{10}$	"
" "	five	"	"	"	90	"
" "	ten	"	"	"	$82\frac{7}{10}$	"
" "	fifteen	"	"	"	$76\frac{7}{10}$	"

9. Regardless of the above facts, concerning the efficiency of this type of machine as an air compressor, a manufacturer recently issued a catalogue, from which the following paragraph is taken:

"The machine illustrated (patent pending) is constructed to stand a pressure of from fifteen to twenty pounds per square inch. In this machine we use a spray of water to pack the machine and prevent backward escapement of air, and at the same time absorb the heat caused by compression. The water is carried over into the separating tank and automatically drained off. This new device, after careful and exhaustive test, proves to be all that we expected of it, and enables us to maintain fully as high an efficiency under high pressures as we can under one pound or less. For work where a pressure of from two to eighteen pounds is required, we are ready to guarantee a very high efficiency. We contend that the principle of the rotary motion applied to air under high pressure eliminates a vast amount of friction, and hence wear and tear; and when high efficiencies can be obtained, is far more preferable in every respect than the blowing engine."

10. This reference is quoted to support the position taken—that a machine, when misapplied, cannot be made successful, and such a policy is sure to bring it into bad repute.

We consider a rotary machine of this type out of place when working in elastic fluids at more than five pounds difference of pressure. The proper application of rotary positive machines when operating in air or gas under differences of pressures from eight ounces to five pounds is where constant quantities of fluid are required to be delivered against a variable resistance, or where a constant pressure is required and the volume is variable. These are the requirements of gas works, pneumatic-tube transmission (both the vacuum and pressure systems), foundry cupolas, smelting furnaces, knobbling fires, sand blast, burning of fuel oil, conveying granular substances, the operation of many kinds of metallurgical furnaces, etc.

11. The efficiency of a rotary pump depends on the size, the speed at which it is operated, the pressure under which it is working, and its construction. The capacity varies as the square of the diameter of the cylinders, or distance between gear centres, and directly with the length of the impellers and cylinders. The principal leakage lines are the contact lines between the impellers, and between the impellers and cylinders, as the impellers can be fitted quite closely at their ends. It is obvious, therefore, that in a large machine the per cent. of slip due to the working pressure and the clearances is less than in a small one. For example: One blower has a capacity of 12½ cubic feet per revolution, its shaft centres are 16 inches apart, and its impellers 48 inches long; another has dimensions just twice these, and its capacity is 100 cubic feet per revolution, or eight times as great. If we assume the machines to have the same clearances, and running under the same speed and pressures, then the per cent. of slip in the larger machine would be only one-fourth that of the smaller, because the leakage lines are twice as long in the larger machine and its capacity is eight times the smaller one.

12. Since the leakage lines are exposed to the working pressure at all portions of the revolution, the slip is practically constant for a given pressure whether the machine be running fast or standing

still. This argues for as high a speed for a blower as is consistent with successful mechanical operation, because the loss due to air friction is inconsiderable if the inlet and discharge are made large. For water, however, questions of velocities are very important, and the speed should be reduced.* The height of a column of air of equal density necessary to produce a pressure of one pound per square inch would be 1,895 feet. If $V=\sqrt{2gH}=8.02\sqrt{H}$, then the theoretical flow at the base of the column would be 8.02 times the square root of 1,895, or 349 feet per second, and for small differences we assume that the velocity varies as the square root of the pressure. Therefore, doubling the pressure doubles the load, and increases the slippage to 1.41 times what it was at the original pressure. We have found the above assumptions concerning the slippage in rotary blowers to be practically correct, after having tested hundreds of them by closing the discharge and counting the number of revolutions of slippage at different pressures.

13. An interesting experience was had with two pumps, each to have a capacity of 25,000 gallons per minute lifted 31 feet, coupled direct to a Corliss Engine, running at about 67 revolutions per minute. We designed them with two air chambers on the discharge and two on the suction side of the pumps, placing them as near as possible to the impellers, the air chambers having connections to the pumps 7 inches in diameter. When we began to operate the pumps we found that they would run smoothly up to 50 revolutions per minute, at which speed a powerful water hammer occurred. We attached an indicator to the discharge side of the pump, 18 feet below the upper water level, and found that the pressure there varied from 5 or 6 pounds vacuum to 30 or 40 pounds pressure. The action on the suction side was similar except that the vacuum was about 12 pounds and the pressure rose slightly above atmospheric pressure.

14. It was this experience which led to the production of the diagram shown in Fig. 110. It also caused the writer to investigate the practice concerning air chambers on piston pumps, and we were surprised at the abuses committed by the users of that type of

* The theoretical velocity of air at one pound above atmosphere and at a temperature of 62 degrees Fahr. is about 349 feet per second, assuming that for small differences of pressures (where there is relatively small expansion) the velocity of flow follows the law of falling bodies. A cubic foot of air at 62 degrees Fahr. at sea level weighs .076 pound.

pumps. Mr. F. Meriam Wheeler has brought this matter out very clearly in one of his papers,* and it would be well if manufacturers and users of reciprocating pumps would follow his advice.

We corrected the deficiency in capacity of air chambers on the above-mentioned pumps by the addition of more chambers which enabled us to operate the pumps at a speed of 85 to 90 revolutions per minute.

Since then we have made pumps having capacities of 35,000, 40,000, and 50,000 gallons per minute, which are operating under heads of from 8 to 25 feet, and have had no trouble from water hammer.

The writer has taken many indicator cards from engines operating rotary pumps, and finds the combined efficiency of the pump and engine to be from 80 to 84 per cent.

Two large pumping plants are now under way near Beaumont, Texas, for the Treadway Canal and Rice Co., from which we expect to get some excellent records, one plant consisting of four 35,000 gallon pumps, operating under 35 feet head, direct coupled to compound condensing Corliss engines; the other plant consisting of two 70,000 gallon pumps, operating under 10 feet head, direct coupled to tandem compound condensing Corliss engines. These plants are to be operated with oil fuel, and we hope to be able to make accurate duty tests of them and place the records of these tests before the engineering world.

DISCUSSION.

Mr. H. M. Lane.—I would like to inquire of Mr. Wilkin what has been the experience with these pumps with regard to scoring of the casing or impellers?

Mr. Wilkin.—We have had pumps running for three or four seasons in the rice fields of Louisiana and Texas with such water as comes from the drainage of those fields, and the scoring is imperceptible. The lobes and casings are covered with a coating of brown oxide, under which the tool-marks are still present from the machining. In some cases where the water has contained gravel, there has been some scoring of the ends of the impellers.

Prof. Albert Kingsbury.—What are the advantages of the

* No. 884, vol. xxii., p. 439.

cycloidal form over the involute for the impeller? The latter has been more often used.

Mr. Wilkin.—The involute curve starts on a spiral form and goes off to infinity, so that only a portion of the curve can be used for the outline of the impeller; the ends are usually cut off and finished with the arc of a circle. The cycloid is a curve which returns to the pitch line, hence the whole outline of the impeller can be made of epi- and hypo-cycloids. With the involute, the cutting off makes a compression pocket, because the corner of one curve keeps contact until the next corner comes into contact, and this has the disadvantages mentioned in the paper.

Mr. Gus C. Henning.—Will the line contact which is obtained by the use of the cycloidal curve hold the water with as little slip as the cylindrical contact which is gotten with the arc of a circle?

Mr. Wilkin.—While the contact between the impeller and cylinder is theoretically on a line, yet the radius of curvature of the cycloid at that line is nearly as long as the radius of the cylinder, and there is practically quite a long tangent formed between the cylinder and impeller.

The contact between the two impellers is formed by convex and concave curves working together, and this results in a longer contact than if two convex curves were working together.

Mr. James McBride.—There is one point of similarity between the rotary pump and the centrifugal pump, which is that the pistons work inside of a shell. I have had no experience whatever with the rotary pump as shown here, but I have had quite a little with centrifugal pumps. One of the defects in the construction of those pumps I find is that no ample provision has been made for the end wear of the shaft—nothing but a collar on the outside; sometimes a pulley is made to constitute one collar. In a short time the shaft gets end motion and wears off the side of the shell. Then you have trouble with the pump. I have come across one that I have used for several years where the manufacturer made no provision for the end wear of the shaft, so that it jiggles back and forth between the shells and in a little while wears off the sides of the piston and there is a large amount of slip.

With reference to Mr. Wheeler's paper read at the last annual meeting, speaking about his air vessels, I took some part in the discussion. I think I showed very clearly that the question of an air vessel on a pump, either on the receiving side or the discharging side, was not so much a question of location as a question of capacity. I think that is borne out by the experience of this gentleman with rotary pumps, who says he has remedied very bad water hammer by simply increasing the capacity of the air vessel. In the pump that I referred to in my discussion on Mr. Wheeler's paper, the air vessel was put just where Mr. Wheeler says it should not be put, but the result has been perfectly satisfactory. I have had no trouble with it at all, and think it is due, not so much to the location as to the capacity. I make this suggestion to the manufacturers of pumps, rotary as well as centrifugal: Make ample provision to prevent end wear of pistons.

Mr. James G. Winship.—In reference to Mr. McBride's statement, I want to say that I agree with Mr. Wheeler—*i.e.*, that it does make considerable difference as to the location of the suction air chamber. In Mr. McBride's pump the location is all right for that particular arrangement, and no doubt it serves the purpose. But if Mr. McBride had the opportunity to place the suction air chamber in a more favorable position, he would have found considerable improvement. In locating an air chamber on the suction pipe of a pump, the idea is simply to keep the column of water in as continuous a motion as possible. If you place the air chamber in the most favorable position, there will be the least resistance to the free flow of the water, and consequently smoother working of the pump will be the result.

Mr. McBride.—I accept the gentleman's explanation. It frequently occurs that it is almost impossible to put the air chamber where Mr. Wheeler suggests; then do the next best thing: put it as near the pump as possible, and make up in capacity what is lacking in location. We know by experience that in putting pumps and engines in factories which have grown from small units to large ones, that we are obliged to put machinery in places where it is a problem to get it in at all. In that case, if you cannot put the air vessel in the theoretically proper place, put it as near as you can, and make up by making it of larger capacity.

*Mr. Wilkin.**—Mr. McBride, I believe, spoke of the end wear

* Author's closure, under the Rules.

of the impellers, and compared it somewhat with the centrifugal type. Of course in our machines we have very large end surface on the impellers. The speed is very low, say 60 to 100; 60 in the larger pumps, 100 in the smaller. Grease cups can be placed on the ends and give ample lubrication. In regard to air chambers on pumps, the necessity for air chambers in pumps of the positive type is due to the fact that a pump of the piston type or rotary-positive type does not take its water uniformly. It does not discharge it uniformly. There is a variation in the column. Therefore it is a question of inertia of those closed columns on both sides. Now, any method which will cut those columns in two and put an elastic medium there near the pump, will answer that purpose, because you have done away with the inertia of the long column, and have a little short column next to the pump. Of course, in practice, if you have an air chamber, it should be put where the air will be retained in the chamber, not taken away by the action of the water, otherwise the good effect of it will be annulled.

I thank you, gentlemen, for the interest you have taken in this, and hope that I may be able to present the results of some of our large work in an accurate way in the future.

No. 971.*

THE METRIC SYSTEM.†

BY F. A. HALSEY, NEW YORK CITY.
(Member of the Society.)

1. THE situation at Washington regarding our system of weights and measures demands the most serious consideration. The testimony before the House Committee on Coinage, Weights and Measures was overwhelmingly one-sided, and, weighing such testimony in the only way that Congressmen can, the committee could bring in no other report than the one it did, recommending the passage of the Metric System bill. Scientific and practical men of the front rank, as well as engineering, scientific and trade societies everywhere, are calling for this measure. The Western Society of Engineers, by a mail ballot, voted for it by over 5 to 1. The Franklin Institute, with Samuel Vauclain, James Christie, and Wilfred Lewis on its committee, has also indorsed it. With the report of the Franklin Institute were transmitted to the House committee 21 letters from "various large manufacturing firms, particularly manufacturers of machinery" (page 104),‡ which had been received in answer to a circular letter of inquiry, of which 20 favored the metric system. To cap the climax, the resolutions of this Society at its last spring meeting (see *Transactions*, vol. xxiii, page 435), have been interpreted at Washington in the manner indicated by the following extract from a news article,

---

* Presented at the New York Meeting (December, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

† For additional references on this subject consult *Transactions* as follows:
No. 4, vol. i., page 30: "Metric System." Coleman Sellers.
No. 721, vol. xviii., page 492: "Metric *versus* Duodecimal System." Geo. W. Collès.
No. 258, vol. viii., page 686: "President's Address." Coleman Sellers.

‡ Unless otherwise specified or obvious from the context, page references are to the pamphlet containing the testimony before the House Committee on Coinage, Weights and Measures.

dated at Washington and published in the *Iron Age* for June 26, 1902:

"The action of the American Society of Mechanical Engineers with regard to the metric system, which was fully reported in the *Iron Age* of June 5, has greatly encouraged the members of the House committee and has decidedly improved the prospect for the passage of the metric system bill. * * * Although the personal bias of the members of the committee was well known, it was assumed that their action was not without full authority, and the resolutions adopted by the society disavowing the action of these individuals and discharging the 'metric opposition committee' has been very gratifying to the advocates of the pending bill."

2. The pro-metric argument is, substantially, an *a priori* argument. The metric advocates adopt the methods of the old philosophers who laboriously sought to prove what ought to be. My method is that of modern science, which interrogates nature in order to learn what is. For instance, they tell us how easily and how quickly this nation ought to make this change; I shall show how slowly and laboriously France and Germany have made the change. They will say that we ought to adopt this system to please our foreign customers; I shall show that our foreign customers do not care one picayune whether we adopt it or not, and I shall prove it by a flood of evidence.

Errors of and Misrepresentations by the Metric Advocates.

3. In their efforts to show how easily the metric system may be adopted by this country, the metric advocates endeavor to create the impression that it has already made considerable progress. Thus Mr. Stratton, Director of the National Bureau of Standards, stated at the hearings of the House committee, that the Carnegie Steel Company were about to issue a metric edition of their hand-book. I quote here because this is too important to be treated in any other way. In questioning Mr. Linnard Mr. Stratton said (page 182): "And that the Carnegie people are about to issue a hand-book in which all the formulæ are printed in the metric system? Has that been called to your attention?"

4. Following is an extract from a letter by the Carnegie Steel Company:

"In reply to your inquiry, we beg to advise that we have not issued a hand-book containing formulæ according to the metric system, and have no present expectation of doing so."

Mr. Stratton repeated this statement before the Western Society of Engineers,* and with it made another, his words being as follows: "The National Tube Works has one of its largest mills fitted up for the system. The Carnegie people are getting out their hand-book in the metric system."

Following is a letter from Mr. P. C. Patterson, Mechanical Engineer of the National Tube Company:

> "I find the following conditions prevailing in regard to the use of the metric system in this company's business:
>
> "Lap-welded pipe for foreign countries using the metric system is made to either the American or English standard. Special lap-welded goods ordered to metric measurements are made to the nearest fraction of an inch, no attempt being made to get closer than within $\frac{1}{16}$ inch of the dimension called for.
>
> "Seamless tubes are made to exact metric measurements when ordered by metric measurements."

On page 11 will be found the following dialogue:

> *Mr. Shaffroth.*—Do the jewellers use the metric system in France?
>
> *Mr. Troemner.*—In France? Oh, yes.
>
> *Mr. Shaffroth.*—And wherever the metric system is adopted?
>
> *Mr. Troemner.*—Yes, sir.
>
> *Mr. Shaffroth.*—Wherever the metric system is adopted and is in practical operation is there any other system at all used?
>
> *Mr. Troemner.*—None that I know of.

5. While more will follow later, the following extract from a letter by Tiffany & Company will supply Mr. Troemner with the information which he now lacks:

> "In reply to your letter, which we referred to our Mr. Kunz, we beg to state that the carat is the standard of weight for gems all over the world."

The above letter was written in reply to the categorical question: Do French and German jewellers use the gram or the carat in weighing diamonds?

6. A favorite diversion of the metric advocates is to represent the famous report of John Quincy Adams as strongly pro-metric. Thus Mr. Tittman (page 32) said: "Mr. John Quincy Adams, who gave four years to the preparation of his report, speaking in the most glowing terms of the metric system, said that if it could only

---

* See *Journal of the Western Society of Engineers*, August, 1902, page 344.

be adopted it would be an ideal one." Again *in the report of the House committee* * appears the following:

"He [J. Q. A.], however, advised delay until the metric or international system, which was then in its infancy, had been more fully tried, and to which he referred in a most glowing tribute as possessing all the requisites of a simple, uniform, and workable system of weights and measures."

Following are a few extracts from Mr. Adams' report: †

"The metrology of France is a new and complicated machine, formed upon principles of mathematical precision, the adaptation of which to the uses for which it was devised is yet problematical and abiding, with questionable success, the test of experiment." (Page 178.)

"The decimal numbers applied to the French weights and measures form one of its highest theoretic excellences. It has, however, been proved by the most decisive experience in France that they are not adequate to the wants of man in society." (Page 197.)

"This illustration * * * will disclose to our view the causes which limit the exclusive application of decimal arithmetic to numbers, and admit only a partial and qualified application of them to weight and measure." (Page 198.)

"Thus, then, it has been proved by the test of experience that the principle of decimal divisions can be applied only with many qualifications to any general system of metrology; that its natural application is only to numbers; and that time, space, gravity, and extension inflexibly reject its sway." (Page 202.)

"Nature has no partialities for the number ten, and the attempt to shackle her freedom with them (*sic*) will forever prove abortive." (Page 204.)

" * * * As this system is yet new, imperfect, susceptible of great improvement, and struggling for existence even in the country which gave it birth ‡ * * * " (Page 217.)

* This report may be found in full in the *Journal of the Western Society of Engineers* for August, 1902. The present quotation is from page 351.

† This famous paper is not out of date nor will it ever be. It may be found in *The Metric System*, by Charles Davies, to which the page numbers refer, a book which is out of print and scarce. The quotations in the text were obtained from a copy in the Boston Public Library:

The book by Professor Davies (he of the mathematical text books of a generation ago) is the report of himself and Robt. S. Hale as a committee of the University Convocation of the State of New York. It gives the conclusions of an investigation made at the request of Hon. J. A. Kasson, Chairman of the House Committee on Coinage, Weights and Measures in 1866. The reports of J. Q. Adams and of Professor Davies represent the conclusions of the only American investigations of this subject worthy of the name which have ever been made, and *both of them are unfavorable to the adoption of the system.* In the cases of Messrs. Davies and Hale, it is to be noted also that they began the investigation as metric advocates and finished it as metric opponents. Could these reports be circulated as they deserve to be, the metric agitation would die a natural death.

‡ Note the words "struggling for existence" *after twenty-seven years* of " the most stupendous and systematic effort ever made by a nation to introduce uniformity in their weights and measures." (Mr. Adams, page 174.) And yet

"But were the authority of Congress unquestionable * * * it is believed that the French system has not yet attained that perfection which would justify so extraordinary an effort of legislative power at this time." (Page 268).

"For all the professions concerned in ship or house building and for all who have occasion to use mathematical instruments it [the metre] is quite unsuitable * * * This inconvenience, great in itself, is made irreparable when combined with the exclusive principle of decimal divisions. * * * This decimal despotism was found too arbitrary for endurance. * * * The choice of the kilogram or cubical decimetre of distilled water as the single standard unit of weight with the application to it of the decimal divisions was followed by similar inconveniences * * * But on the other hand, decimal divisions are still more inapplicable to measures of capacity for liquids than to linear measures or weights." (Pages 199, 200, 201.)

7. Mr. Adams had great admiration for the conception and for the efforts of the French Government in its endeavor to establish a universal system of weights and measures. There are also in the report expressions of approbation for the system which certainly do not seem to be consistent with the above citations, but that the report as a whole can be considered as an endorsement of the system in "glowing" or any other terms is simply not so.

What is now the chief argument against the adoption of the system—the anchoring of existing units in manufacturing industry—is chiefly a growth since Mr. Adams' time; but, nevertheless, he saw clearly the difficulty of the change, and much of his report is devoted to this as distinguished from his strictly judicial analysis of the merits and demerits of the system. To illustrate this difficulty he (page 150) draws a striking picture of the then far from complete adoption of our system of currency (already thirty years old), and on page 149 he refers to a change of this kind as "a revolution by all experience known to be infinitely more easy to accomplish than that of weights and measures."

The Persistence of Old Units in German Textile Industries.

8. The testimony before the House committee is sprinkled with opinions that this great change can be made in from three to five years (Mr. Bates, page 92, seems to think "a year or two" will be sufficient).* In this matter we do not, however, need to re-

the metric advocates represent Mr. Adams as endorsing the system in "the most glowing terms," and profess to believe that we can make this great change in from three to five years.

* The bill as reported by the House committee, with recommendation to passage, makes the system the legal standard four years from January 1 next.

gard opinions at all, but may apply the scientific method at once and consult the facts.

At the presentation of this paper there were offered for inspection a collection of French and German books from the library of the *Textile World*.* These books present a condition of things which is absolutely startling. As instructive as any is a little German book of 105 pages, "Kalkulator für Artikel der Textilbranche" (Calculator for Articles in the Textile Industries), by Friedrich Frowein, third edition, 1901. The object of this book is to give a *simplified* system of calculating for textile fabrics, and it discloses a condition of things in German-speaking Europe compared with which our own is simple indeed. This condition is due to the fact that there are still in use nine different ells in addition to the metre and the English yard. These ells are divided into inches, an inch ranging all the way between $\frac{1}{20}$ and $\frac{1}{36}$ of an ell, and such extraordinary ratios as these being still in use:

Prussian ell..................	25½ inches.
Würtemberg ell..............	34¼ inches.
Vienna ell....................	29½ inches.

In brief the book shows that there is still in use in German textile mills an absolute medley of ells, inches, yards, metres, kilograms, and pounds, combined with a vast number of systems of yarn numbering based upon these different units of length and weight, while towering above all these systems of yarn numbering are found the English yard and pound in all branches except the silk industry, in which the metric system cuts a very small figure.

9. In the *Textile World* for October, 1902, is an article into which has been lifted bodily the following specimen of Frowein's *simplified* calculations of the cost of a piece of worsted cloth:

---

* For invaluable assistance in the selection of these very few of many salient facts regarding the persistence of old units in the French and German textile industries, I am indebted to Mr. S. S. Dale, editor of the *Textile World*, who has also kindly revised the present and the following sections.

Kalkulation.

Ein Stück einen Meter breit und hundert Meter lang.

Kette per cm 24 Faden 48r Weft (Double).
Einschuss per cm 28 Schuss 40r Single Weft (einfach).
Rieth (Blatt) per cm 12 Rohr 2fädig.

Englische Weife.

Kette: 48r Weft à 100 Meter $3\frac{3}{4}$ Gr.			
2400 Faden = 240000 Meter =	= 9000 Gr.		
Verschmälerung 4 %, 96 Faden = 9600 Meter =	360 „	= 9360 Gr.	
Einkreuzen 8 % = 19968 Meter		749 „	
		10109 Gr.	
Stoff per engl. Pfd. Mk. 3.—			
Färben „ „ „ „ —.20			
1 engl. Pfd. Mk. 3.20, daher obige		10109 Gr.	Mk. 71,89
Einschuss: 40r Single Weft à 100 Meter $2\frac{1}{4}$ Gr.			
28 Schuss per cm = 280000 Meter = 6300 Gr.			
Einkreuzen 2 % = 5600 Meter =	126 „ =	6426 Gr.	
Stoff per engl. Pfd. Mk. 2.—			
Färben „ „ „ „ —.20			
1 engl. Pfd. Mk. 2.20, daher obige		6426 Gr.	„ 31.42
			Mk. 103.31
Verlust 6 %			„ 6.20
			Mk. 109.51
Fingirter Satz siehe erste Kalkulation 50 %			„ 54.76
			Mk. 164.27
Spesen und Zinsen 10 %			„ 16.43
Herstellungskosten			Mk. 180.70

Zu obigem Stück sind erforderlich:

Kette 269568 Meter = 294933 Yards à 560 Yards 1 Zahl = $526\frac{2}{4}$ Zahlen
Einschuss 285600 „ = 312473 „ à 560 „ 1 „ = 558 „

A GERMAN ESTIMATE OF COST OF A WORSTED FABRIC AT THE PRESENT TIME. THE ENGLISH STANDARDS ARE MARKED WITH DOTTED LINES.

Mr. Dale describes the operations performed in this illustration thus:

"The raw material is purchased by the *English pound*. The finished goods are sold by the *French metre*. The yarn counts are *English*, while the length and width of the finished goods are *metric*. The length of the yarn is expressed in *metres*, while the counts are *English*, based upon the *yard* and the *pound*. From this hodgepodge the weight of the yarn is calculated in *grams*, which is extended by another arithmetical somersault at a price given in marks per *English pound*, and to cap the climax the total length of the yarn in *metres* is reduced to *English yards* and then to *English skeins* of 560 yards each.

"There is no theory here. This estimate is an example of German practice at this moment, and yet men can be found who say that the metric system was adopted in Germany in two years without inconvenience, some asserting they were present when the trick was done; and stranger still, other men can be found who believe it."

Note that this example is relatively a simple one, because it contains none of the ells nor inches, but relates to yards, metres, pounds, and grams only. It hence represents exactly the condition which the adoption of the metric system would bring about in our own mills.

10. A second German book is "Garn-Nummerirungen, Haspelungen und Vergleichende oder Umrechnungstabellen" (Yarn Numbering, Reeling, and Comparative Reckoning Tables), by Heinrich Kutzer, 1901. This book contains a great number of tables for comparing and reducing the numerous units of length and weight, and is of wider scope, geographically, than the first one cited. It shows that 21 ells are in use in European countries in which the metric system is nominally established.

A third German book is "Methodik der Bindungslehre und Decomposition für Schaftweberei" (A System of Weaves and Analysis for Harness Weaving), by Franz Donant, 1901. This contains an explanation of the various systems of yarn numbering used in German-speaking countries. It is chiefly significant because of the order in which these systems occur, as the English system heads every list except the last, in which there is no English system. Following are the lists:

Cotton—English, French, metric (note the *French*).

Linen—English, Austrian (no metric).

Jute—English only.

Worsted—English, metric.

Woollen—English, Austrian, Prussian, Saxon, metric.

Silk—Milan, Turin, Lyons, metric.

11. A fourth German book is "Mechanische Technologie der Weberei" (Mechanical Technology of Weaving), by G. Herman Oelsner, eighth edition, 1902.

This is an elaborate and beautifully printed treatise of 942 pages. In it page after page is devoted to conversion tables giving metric equivalents of Rhenish, Leipsic, and English inches, as well as of Leipsic and Berlin ells and of English yards.

On page 130 may be found the metric equivalents of the following ells: Prussian, Saxon, Brabant, Bavarian, Wurtemberg, Baden, Vienna, English, Danish, Swedish, Russian. On page 74 he refers to the Cockerill system of yarn numbering used in Belgium, and which is based on the length of 2,240 Berlin ells.

On page 75 he refers to six systems of numbering for carded woollen yarn as follows: Prussian, Saxon, Austrian, English, Elbœuf, Sedan.

On page 121 are some striking illustrations of the annihilation of vulgar fractions by the metric system. In a table giving the number of threads per French inch and per centimetre the following mixed numbers occur in the first line: $11\frac{58}{131}$, $31\frac{1}{29}$, $24\frac{106}{131}$, $67\frac{7}{29}$ A footnote to this page states that the French inch is used for gauging the set of fabrics in Switzerland.

12. In this connection I clip (italics mine) the following from the *Textile World* for September, 1902:

> "A writer in the *Leipziger Monatschrift fuer Textil-Industrie* expresses his conviction that German cotton manufacturers must abandon the hope of driving from that country the English system of yarn numbering. This view has been strengthened, undoubtedly, by the action of the tariff committee of the Reichstag, which, owing to the strong opposition of German mill owners, has rejected the proposal to compel the exclusive use of the metric system for yarn, and has arranged the yarn schedules in the new tariff bill in accordance with the English counts, *thus continuing the official German sanction of the English system.*"

The English system of yarn counts carries with it the yard and the pound, and this recognition of them is an official confession that twenty-eight years of effort to introduce the metre and the kilogram as a basis of yarn counts has resulted in failure.

I also give without comment, except italics, the following from *Wochenberichte Handelsblatt der Leipziger Monatschrift fuer Textil-Industrie*, July 16, 1902:

> "At the session of the [German] Tariff Commission on the 24th of June, the question came up regarding the employment of the metric system for cotton yarn. According to one delegate, Muench-Ferber, who is also a partner in a woollen and cotton weaving mill, 'the use of the metric system for yarn would lead to ungodly disorder (heillose Verwirrung) in the domestic weaving industry, *since our machines are constructed for the use of the English numbers.*' "

The Persistence of Old Units in French Textile Industries.

13. In France the condition is, if possible, still worse. Illustrating this may be cited "Traité Théoretique et Pratique de Tissage" (Theoretical and Practical Treatise on Weaving), by Paul Lamoitier, 1900. This is a standard French work on textiles of 573 pages. On page 27 may be seen a comparative yarn table giving equivalents of the following systems of yarn counting, which are thus compared because they are still in use:

Worsted—Metric, Roubaix, Reims, Fourmies, English, German.

On page 52 is a similar table for

Silk—Lyons, Italian, metric.

On page 60 is a table for

Cotton—English, French, metric (note the French again).

On page 63 is an illuminating sentence. Opening a section on yarn numbering for linen, hemp, and jute is this sentence: "On emploie le titrage anglais" (We use the English system of numbering yarn). Following this comes the following beautiful example of how the decimal system has swept all before it in France:

> "The lea is 300 yards, or 274.2 metres; 12 leas make a skein of 3,600 yards; 100 skeins a bundle of 360,000 yards."

On page 88 the author gives a table showing the weight of weft or filling for one metre of worsted cloth by the Fourmies (an old French) system, and on page 87 states that "this table is given because the Fourmies is used to a greater extent than any other system of yarn numbering for worsted."

In the early part of the book, on page 24, the following may be seen:

> "We shall further on study the counts of silk, cotton, linen, etc. We regret extremely these anomalies which obstruct business, lead to serious errors, and wantonly complicate all calculations."

14. Perhaps the most curious example of all in the French textile industries is the count of the weft threads in the fabric—the number of "picks" of the loom. Here, if anywhere, it would seem to be easy to introduce the centimetre, but nevertheless the French weaver counts his picks by the inch (*pouce*), and (save the mark!) 37 French inches equal 1 metre. On page 90 of the book under notice is the following:

> "The filling is ordinarily reckoned arbitrarily by the quarter inch, and it is necessary, before the calculation of a fabric, to convert the picks per quarter inch into picks per centimetre. There are 148 quarters of an inch in a metre; 1 centimetre is equal to 1.48 quarters of an inch; 5 picks per quarter inch are equal to $7\frac{4}{10}$ picks per centimetre."

In *L'Industrie Textile*, the leading French textile journal, for August 15, 1902, is a four-page description of a new worsted-spinning frame, and an account of a test of it. At the conclusion of the mechanical description the capacity of the machine is given for different sizes of yarn. These sizes are given in the Roubaix system, under which the test was made, which figures are then translated into the metric system.

15. It is wholly impossible in a few paragraphs to even indicate the confusion and complexity which are shown by these books to prevail in the weights and measures of metric Europe. The complications introduced by them into textile calculations are beyond belief.

In these books are pages after pages of conversion tables between the various ells and between the ells and the yard and metre, added to which are conversion formulas making a total which is fairly maddening. These comparative calculations and reductions are an essential part of all French and German textile literature. A French or German work on textiles dealing with metric weights and measures alone would be worthless to 99 per cent. of the French and German textile industry. *Note that all books cited are modern.*

They are but a small portion of those in the possession of the *Textile World,* the whole collection offering, in fact, an embarrassment of illustrative material.

16. A concise statement of present-day French practice from a recognized French authority will, no doubt, be considered by some to possess greater weight than the most obvious deductions from books, and, very opportunely, M. Paul Lamoitier, the author of the book last above cited, publishes a leading article on "The Unification of Yarn Numbering" in *L'Industrie Textile* for October 15, 1902, of which journal he is, I believe, the associate editor. From advance sheets of the *Textile World* for December I make the following extracts from a translation of this article:

"It is absolutely unworthy of us French who were the first to find and apply the metric system to retain the *aune* and the *denier* for measuring silk. Ah! these Americans are not considerate of our feelings and they are right. We are as much in the anarchy of weights and measures for the textile industry as at the time of the Revolution, for we have the *denier* of Montpelier and of Milan, for silk, with the *aune* as a unit of length. We still have the diverse standards of Roubaix, Fourmies and Reims for worsted, the *moque* of Sedan, the *livre,* the *quart* and the *sous* of Elboeuf, the yard for linen, etc. Ah! the famous *aune,* do you know its equivalent? Exactly 3 feet 7 inches 10 lines and 10 points, or in other words, 1.188447 metres, the foot being equal to .324839 metres and divided into 12 inches, the inch into 12 lines and the line into 12 points. [The foot and inch referred to here are obviously the French foot and inch.]

"The yarn count in the north of France is a length and in the centre, a weight. I will take my oath that the manufacturer of Rouen, if he has not studied each section separately, has no idea what is the standard of Reims or the *denier* of Lyons or Milan. And on the other hand, the manufacturers of Reims and Lyons are likewise puzzled in making comparisons of the diverse numberings of the diverse materials.

"And this is the reason why they are right in mocking us when they say we do not use the metric system for numbering yarn and for weaving calculations. Nothing is more arbitrary than to reckon the yarn by the thousand metres and the width of the cloth and the picks of the filling by the inch. It is nonsense and a derision. Note also that, while I speak here only of France, I could say as much of all Europe."

Later in the article the author calls for a compulsory law to compel the use of the metric system in French textile industries, and adds:

"The advantages? It would put a stop to the chaos which the Americans ridicule. * * * In short, they would not ridicule us any more. It is not pleasant to be thus continually ridiculed by foreigners, especially when they have good reason for doing so. * * * In the face of foreign sarcasm it [the metric system of yarn numbering] should be established at the earliest possible moment."

17. In the November issue of *L'Industrie Textile,* M. Lamoitier has another article in which he points out an "annoying anomaly," namely, the fact that French loom widths are expressed in quarter yards. Referring to the results of a change in these widths to metric dimensions he adds (italics mine):

"*We have now a confusion which will spread throughout the world and increase with the general adoption of the metric system.*"

The references to American criticism of French practice in the above relate to articles in recent issues of the *Textile World.* The anti-metric fight which Mr. Dale has conducted in the columns of that journal, as well as his assistance in the preparation of this paper, deserves all the recognition which I can give.

At this point it is interesting to quote the testimony of Dr. Wiley (page 51): "There is only one great objection to the metric system, and that is, it is going to weaken our mathematical abilities, because we will not have this immense practice in computation which we have to have now." The system seems not to have had that effect in France and Germany.

18. In the simplicity and uniformity of its weights and measures this country is fortunate beyond comparison with Continental Europe.

The meaning of all this, and the lesson to be learned from it, is not, however, that the textile industries of France and Germany are infinitely worse off than our own as regards their systems of weights and measures, nor that their textile calculations are infinitely more laborious than ours (both of which, however, are facts), but that twenty-eight years after the compulsory adoption of the metric system in Germany the old units still persist to an extent calling for such books, and that, in France, a hundred years of time, national pride, and a despotic government combined have not succeeded in killing the old units. The only effect of the adoption of the metric system in both of these countries has been to add a new set of units to the old ones. Shall history repeat itself here?

19. If the reader wishes further confirmation of these facts, he may find it in the "Report of the International Congress for the Unification of the Numbering of Yarn," held at the Paris Exposition of 1900. From Mr. C. J. H. Woodbury's translation I make the following extracts:

M. De Pacher "believed that the numbering of yarns could not be introduced in every country except by the authority of a law positively ordering its use to take place on a certain date for all textile industry and for all commerce in every kind of yarn. The change would be made by a law, or it would not be made at all. He was convinced that the spinners who commenced to wind and to number their products according to the resolutions of the Congress before a law should be enacted to forbid the sale of yarns wound and numbered according to the old way, would probably keep their yarns and would be obliged to sell at a loss."

Note the agreement of this speaker with M. Lamoitier, that after 110 years of the metric system in France *more compulsory law is needed.*

Said the Corresponding Secretary of the Congress, M. Ferdinand Roy (italics mine):

At present, one of the arguments of the English Government is this: the international commerce is carried on under the English numbering and this proves how much this numbering has entered into the customs so that *even in certain countries where the metric system is obligatory, the custom tariffs are established for yarns according to the English numbering.* * * * For raw and finished silk, France has maintained up to the present time the old standard; the grain or denier (a copper coin weighing 1¼ grammes) being the unit of weight and the ell being the unit of length. The legal standard indicated by the law of June 13, 1866, and expressing the weight in grammes of a small skein of 500 metres has never been adopted by commerce.

Said M. Edouard Simon, Secretary of the Commission of Organization (italics mine):

"We have thought that there would also be an opportunity to modify, in conformity with the conclusions of the former Congresses, the French law of June 13, 1866, in accordance with which the standard of silk is represented by the mean weight expressed in grammes of a small skein of 500 metres, the sample being made upon 20 small skeins of the same length.

"*This legal standard has remained a dead letter.*"

20. Contrast this experience with the expectations of the prometric witnesses before the House Committee on Coinage, Weights and Measures, that our law will effect the transformation in from three to five years.

The secretary also read from a former opinion of M. De Pacher, as follows:

"It is certain that yarns divided and numbered after the metric system will be unsalable in the greater part of European markets as long as it is permissible to buy or sell yarns divided according to the old systems to which many generations have been accustomed."

Said the English delegate, Mr. Brigstocke:

"The international unification of the numbering of yarns based on the metric system, according to the opinion of the English Government, is not, under the present circumstances, acceptable with us, and I should add that this opinion is participated in almost unanimously by the English spinners themselves."

Contrast this with the opinion of so many (including Lord Kelvin), that if we will only jump into this bottomless pit England will be sure to follow.

The General Persistence of Old Units in France.

21. From M. Laurence V. Benét, artillery engineer for Hotchkiss & Cie., of Paris, I have the following:

"Outside of Paris, and the other large cities in France, the trades-people * consistently violate the law by using the old measures, the only exception being the locksmiths, bellhangers, etc.

"My experience has been, that every Frenchman, when questioned, will start out by saying that the metric system is universally used, and is giving perfect satisfaction, but when pressed closely will readily admit that among the lower classes, the old weights and measures still persist."

From M. L. H. de L'Espée, a French mining engineer and believer in the metric system who is now connected with the National Association of Manufacturers, I have the following:

---

* I infer that this word refers to mechanics and not to merchants.

"Of course, there is everywhere to be found a spirit of routine, and perhaps stronger in France than anywhere else. People who have been used to certain standards during their whole life, are not willing to change them at once. There is no doubt that old measuring standards are still largely in use in many parts of France.

"In the matter of length measurements, the size of a man will be expressed in pieds (feet) oftener than in metres, in the familiar language. The aune (1.20 metre) is still often used in measuring dry goods, in some provinces. The lieue (league) of 4 kilometres is often spoken of in computing distances. As to the mille marin or noeud (knot), the predominance of England in all matters pertaining to navigation is sufficient explanation for its retention in naval vocabulary.

"In the matter of area measurements, the arpent, equal to about ½ hectare, is still largely used. However, its value is variable in the different provinces, which goes to show the usefulness of the hectare provided by the metric system. In Lorraine, the jour (one man's day work) is still the predominant unit in farm measurements.

"For grain measurement, the bushel (boisseau) is still used in many provinces. For liquid measurements, there is still an endless variety of standards, the pièce of 228 litres and the tonneau of 4 pièces in the Bordeaux region; the feuillette of 105 litres in Burgundy; the mesure of 44 litres in Lorraine. Wine crops in Lorraine will invariably be computed in so many mesures par jour. Even in Paris wine is often retailed by the setier.

"For lumber and firewood measurements, the metric stère has never proved a favorite. Firewood is almost exclusively sold by the cord, and lumber is usually sold by the dozen of solives, madriers or planches, each of these denominations having fixed sizes as to length, width and thickness."

22. Following are extracts from a letter by an American engineer who has lived in Paris for some years and whose experience in Continental Europe dates from 1889. He is a graduate of the Massachusetts Institute of Technology, and occupies a leading position; but his connections are such that he desires that his name be not mentioned.

"It is rather singular that the decimal division and multiplication of the metre or kilogramme do not appear to suit various industries for widely different reasons. In order to give you a few examples of this I have extracted some paragraphs from a well-known and very useful handbook in the French language, entitled Formulaire de l'Electricien, edited by M. Hospitalier, who happens to be an authority on the subject we are now discussing.

"The most striking example and one which appears to provoke the wrath of M. Hospitalier is the Cheval-vapeur corresponding to the English horse-power. You will see that he considers the cheval-vapeur an empirical unit. M. Hospitalier's contention is that the Poncelet or 100 kilogrammetres per second, the metric and decimal unit of power and not the cheval-vapeur or 75 kilogrammetres per second, should be adopted. You will see that M. Hospitalier hoped to see this logically defined unit accepted by the International Congress of 1900. As he states, routine got the better of logic in the discussion, and the cheval-vapeur obtained the sanction of the Congress.*

23. "The other extracts concerning Elasticité and Unité de Chaleur refer to the confusion resulting from the use of several industrial units. I have also extracted the paragraphs on Unité de Longueur and Unité de Masse since they very clearly set forth the difference between the theoretical metric units of length and mass and the arbitrary standards on which the metric system is based.

"I send you, by this same mail a copy of *Le Matin*, a Paris morning paper of good standing. If you will refer to the blue pencil marks you will probably be surprised to find so many industrial units of measure which are neither decimal nor metric.

"Of course, when it comes to making out a bill or any business document where the amounts of material are specified, it is necessary, according to French law, to use the units of the metric system in conveying this information. If this is not done you run the risk of a fine.

"On page 5 under the heading *Bulletin Commercial du 5 Janvier*, you will find short paragraphs on the trade in various merchandise. In the paragraph *Spiritueux* you will find the stock is 11,800 pipes and that the sales were 535 pipes. The pipe is, of course, an English measure, equivalent to 105 gallons. Whenever it is necessary to refer to its contents for the purpose of billing or measuring, the litre measure is of course employed.

* Fancy changing the value of the horse-power at this late date! The proposition is no more absurd than the proposition to change other established units, but it should assist engineers in classifying this movement as a simple fad.

24. "In the paragraph *Sucres* the trade unit is the sac, and under the heading ***Depêches Commerciales***, you will find the sales of cotton given in balles, and of coffee in sacs. It is more than probable that the sacs of sugar and of coffee do not contain the same number of kilogrammes of material any more than they contain the same number of pounds. They are nevertheless non-decimal units and, like many others I could find, if I had the time, are sanctioned in French commercial affairs. It could not well be otherwise.

"I received recently an advertisement of a coal and wood merchant who classified his wood as follows:

$$\text{Bois (1) traits} = \frac{1.\text{m } 14}{2} = .\text{m } 57$$

$$(2) \quad " \quad = \frac{1.\text{m } 14}{3} = .\text{m } 38$$

$$(3) \quad " \quad = \frac{1.\text{m } 14}{4} = .\text{m } 28$$

$$(4) \quad " \quad = \frac{1.\text{m } 14}{5} = .\text{m } 23$$

25. " The industrial non-decimal unit in this case is the trait. The stère is the decimal unit of wood measure of the metric system, equal to one cubic metre, and measures 1.14 metres in length of wood by 0.88 metre by 1.0 metre. Consequently one trait refers to the piece of wood which is obtained by cutting the piece of 1.14 metres into two equal parts. The piece known as 2 traits is obtained by cutting the 1.14 metre piece into three equal parts, etc. Although the stere is the decimal unit of wood measure in the metric system, the manner of making up the cubic metre clearly indicates that the old-fashioned method of cutting wood to a length of 1.m14 has not been superseded by cutting to 1 metre lengths. The only thing to do in this case was to make the wood pile 0.m88 high to obtain the cubic metre or stere. It seems to me that this is an instance of adhering to an old well-established practice in spite of the supposed advantages of the decimal units of the metric system. The wood merchant has taken the precaution to give the lengths of his wood in metric measure 0.m57, 0.m38, etc., probably to avoid the fine.

26. " If you will refer to page 6 of the *Matin*, you will find several advertisements of wine dealers or producers. Four of them refer to the pièce and only one gives the contents, stating that his

pièce contains 228 litres. Three offer their wine in quantities of 109, 215, 218 and 228 litres; the first figure representing the demie-pièce and the other three figures representing the pièce, the contents of which varies throughout France, and which is fixed in certain territories only. That is, a pièce of Bordeaux would contain (according to law) a certain number of litres and a pièce of Burgogne contains another number of litres. The content is evidently measured in litres, but these units of demie-pièce and pièce may be considered as non-decimal industrial units of liquid measure.

"Since writing the above I have visited one of my friends in the country, about one hour's ride on the railway from Paris. I find the following units in current use in this market town.

"The setier containing 156 litres is used for the sale of agricultural product, as grain, potatoes, etc.; the minot, equal to $\frac{1}{2}$ mine or $39\frac{1}{3}$ litres, for the sale of apples; the quarteron for the sale of eggs or nuts, equal to 26 of each; the feuillette of wine, containing 135 litres. For sale of land the non-metric units of perche and arpent are still used. Land is also measured in journaux (plural), journal (singular), non-decimal industrial units of land measure. These words are used in the printed notices of sales posted up by the Notaries Public, and are always followed by the content in metric measure. I was shown some recent catalogues of brushes in which everything was sold by the ligne, the pouce and the douzaine. For that matter many things are sold by the dozen and gross in France and not by dizaines or 10's.

27. "If you will refer to stock exchange quotations in the *Matin* you will find a curious condition of affairs which can be easily explained. At bottom of page 3 under the heading *Change* you will find all values given in whole numbers and fractions, as $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$ and $\frac{1}{32}$. Ditto for the New York and Chicago quotations in the same column. On page 5 after the heading Cloture des Bourses Européenes, you will find a mix-up of these fractional parts and decimals. One strange example is the "Exter Espagnols" quoted at $86\frac{3}{8}$ at Bruxelles. This same value under the heading Bourse de Paris (Rentes Etrangères) is quoted 87.95 and 88.02, that is, decimally. Evidently these are matters of custom but it goes to show that there is no great difference in the use of fractional or decimal values, since both are found indiscriminately on the same page.

"I enclose a paragraph which I have torn out of *Le Temps* for December 23, 1902, relative to one of the proposed types of French cruisers. You will see that the maximum speed of the cruiser is expressed in knots, and the maximum possible cruising distance, in sea-miles.*

28. "I have given you examples of a number of non-decimal industrial units with names which are, of course, not found in the terminology of the metric system of measures and weights. They are evidently old measures and old names and their values are expressed, whenever necessary (for special reasons to comply with the law on the obligatory use of the metric system) in the units of the metric system. Others are decimal and metric, but retain the old names for the industrial unit, as quintal for example, and not one of the series of prefixes characterizing the metric units as deca, hecto, kilo, myria, etc. Other units mentioned are supposed to be obsolete or prohibited by law. All this tends to show that certain compromises have been made and that old industrial non-decimal units are respected in France, although their exact values are expressed in metric units whenever necessary. This is the situation some 65 years † after the adoption and use of the metric system was voted obligatory, and rather tends to show the difficulty experienced in introducing a new system of measures and weigths."

Persistence of Old Units in German Mechanical Industries.

29. In the *American Machinist* for May 3, 1900, is an article by Mr. Henry Hess, of Berlin, Germany, on metric screw threads. Mr. Hess is a personal friend and an accomplished engineer, a fact which is attested by his position. He was formerly with the Niles Tool Works of Hamilton, Ohio, and when that corporation established its great branch works in Berlin, under the name of the German Niles Works, he was selected to go to Germany, in order to carry American practice and American methods there, and form a connecting link between the two companies. Please remember that he is actively engaged in machine construction;

* Following is the paragraph in question: "Le cuirassé type *Patrie*, on le sait, a une longueur de 133 m. 80, une largeur de 24 m. 25 et un tirant d'eau de 8 m. 376, avec un déplacement de 14,865 tonnes. Sa vitesse maxima est de 18 nœuds, et sa provision de charbon, qui peut-être portée à 1,825 tonnes, lui donne une distance franchissable de 1,880 milles à la vitesse maxima." Note that this is a government, not a merchant ship.

† The system was originally adopted in 1793. In 1812 this law was repealed, but was reënacted in 1837, and took effect in 1840. During the interval 1812–1840 the system remained the "legal system," but its use was not obligatory.

not in a business capacity, but as a designer and constructor, and he knows the facts from the inside.

Mr. Hess writes (italics mine):

"To work with both millimetres and inches in the same shop, and not infrequently on different portions of a single piece, is too illogical an arrangement to maintain itself. A further complication is brought about by the fact that, though like in name, an inch is a widely varying quantity in different sections. In Germany alone there are at least half a dozen, of which two, the Rhenish and the English, are in such *very general use* as to cause great confusion."

I have a personal letter from Mr. Hess dated at the German Niles Works, September 15, 1902, from which I quote the following (italics mine):

"It is quite true that the great majority of these [old provincial inches] are no longer in use; still it is to-day necessary to be very careful in using rules *that are purchasable in every hardware store*, to make sure whether the inches that are given on the reversed side are Rhenish or English inches.

"Nearly universally *the carpenters and other building mechanics use the Rhenish inch*, and we have occasionally found that men in our shops have made use of their private Rhenish foot-rules.

"As to this matter in France I cannot tell you very definitely, but I believe that similar conditions exist there, though not to as great an extent."

30. At my request Mr. Hess has sent me a collection of these German-made scales, which, in addition to the sacred millimetre, give upon their various edges the English, the Rhenish, and the French inch, the latter measuring 37 to the metre, as already explained. These scales were placed on exhibition at the presentation of this paper. In an accompanying letter, after saying that the purchase was made " in one of the larger retail hardware shops in Berlin, located in the manufacturing district," Mr. Hess goes on to say:

" In talking with the proprietor, I learned that *practically all of the small tradesmen* with whom he has to deal still stick to the use of the inch*, and when they want to sell them anything according to metres, they are informed that they are used to the inch and foot and do not wish to be bothered with the metre."

To understand the full force of this it must be remembered that to sell goods by other than metric measures in Germany is a finable offence, and Mr. Hess's informant has, in fact, paid such fines for acceding to his customers' demands.

* Mr. Hess informs me that by this word he means mechanics, not merchants.

We have also the testimony of Mr. J. H. Linnard, a naval architect of the Navy Department, whose testimony before the House committee is referred to at length farther on. I have a letter from Mr. Linnard dated at Washington, September 5, 1902, in which, after saying, "I recently made a short trip to Germany," he goes on to say:

"The visit I made to Germany was in connection with visits to ship-building yards, and I did not come in contact with other merchants or manufacturers. I made inquiry, however, in the ship-building yards whether the use of the metric system was universal in Germany. I found that in all government work it was universal, but that two yards, one of considerable importance at Flensburg, and one at Hamburg, still use the English system of measurement for their ship work."

31. At the hearings of the House committee Prof. Elihu Thompson, in the course of his pro-metric testimony, read in abstract a letter from Mr. A. H. Moore (page 4), saying:

"Speaking from practical experience of the use of the metric standard in Germany, he says that the Whitworth thread is in almost universal use in Germany and central Europe. * * * * Others [other machines] were designed in Berlin and figured in millimetres, but in these the drill and tap holes were figured in inches. The peculiar reason for this was that, no good twist drills having millimetre dimensions were to be had, while American twist drills were very cheap."

The general use of English pitch threads in Germany is, of course, well known, but it will do no harm to take the fact from a metric advocate's mouth. The discriminating engineer will recall that English sized twist drills make English sized holes, and he will take the use of English sized screws and twist drills as additional evidence that the millimetre has not yet driven the inch from German machine shops, and that Germany is still in the transition period.

32. The letter from M. Benét, of Paris, from which extracts were given in the previous section contains the following:

"In my own experience, I recently had to order a quantity of hardened steel balls from the Waffenfabriken at Berlin in metric Germany. The sizes of these balls were given in $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, and $\frac{1}{16}$ inch, etc., and the balls delivered to me accurately gauged to English, and not to metric dimensions. To cap the climax, the quotations up to $\frac{3}{16}$ inch were so much per *gross*, after that so much per hundred."

Finally, recall Mr. Patterson's letter, which has already been given in correction of Mr. Stratton's mistake. While this letter uses the word *pipe* only, it is a fact that the National Tube Company have a large trade in France and Germany in both boiler tubes and pipe, which, as Mr. Patterson's letter shows, are made to English dimensions. This can only be interpreted as meaning that a good deal of boiler and pipe work is done in those countries on the inch basis.

Do not forget that this condition of things obtains twenty-eight years after the system was made compulsory in Germany.

33. Our manufacturing interests and methods are immensely more developed than those of Germany twenty-eight years ago, with a corresponding increase of difficulty in changing, and yet, with the change incomplete, in Germany after twenty-eight years, these people go to Washington and give it as their opinion that with us, and without compulsion, three to five years will do it all. We are told that we have three kinds of gallons and two kinds of pounds, and must therefore add the litre and the kilogram to the list, but how does our situation compare with 10 ells and half a dozen inches?

In the face of such facts as these what shall be said of such testimony as that of Mr. G. L. Cabot (page 135), that "in the case of Germany and Austria only between two and three years were required to make the complete change, and with highly satisfactory results"? What shall be said of the testimony of numerous United States consuls quoted at such length by Mr. Stratton (pages 163, 164)? A consul sees that the dry goods merchants have changed the tacks upon their counters with which they measure cloth and ribbon, that the grocers have metric weights alongside their balances, and that invoices and bills of lading are made out in metres and kilogrammes, and he concludes that the metric system is in universal use. He can know nothing of the production side of the matter, and a native of France or Germany in many walks of life need know no more. It is, however, on such evidence as this that this case largely rests.

Moreover, what shall be said of such negative testimony as that of Mr. Henning (page 600, vol. xviii., of the *Transactions*): "I have been abroad some, but I have never heard of the English inch being used as a standard in any of the countries I have visited, except, of course, England." As one who is accustomed to weigh scientific data, Mr. Henning will be the first to see that, in view of the fact that others find inches in use everywhere, his own failure to find them counts for nothing.

The Persistence of Old Units in Spain.

34. From Mr. John H. Ball, of Barcelona, Spain, manufacturer of machine tools, I have the following:

"Your paper on the metric system is at hand and I cordially agree with your conclusions. . . . For the two countries [England and the United States] who do more trade between them than all the rest of the world put together, to take on the mixture of the so-called metric countries would be an absurdity.

"Spain is included among the countries whose legal weights and measures follow the metric system. As prior to the passing of the law, each province, and indeed, nearly every town of any importance had its own local scale, the unification of these numerous and bewildering scales by the introduction of the metric system to displace the oldest measures, was a step in the right direction. But between passing a law and compelling its carrying out, there is a wide gulf fixed. Thus while the metric system is universally understood, and nominally reigns, not more than half the everyday business transactions are carried out on a metric basis. Land continues to sell by the 'palmo' or span. Lineal and superficial measures include the 'palmo,' the 'vara,' or yard, which like most of the old measures differs with every province, the 'cana,' about 1½ metres, the 'destre' of from 2.829 metres to 4.214 metres. Oils and wines sell by the 'cuarto,' 'arroba,' 'cántara' and several other measures; cereals by 'fanegas' and 'ferrados'; coal and coke by the 'arroba,' 'quintal' or 'tonelada,' and the last mentioned is the only one of the lot that is approximately an exact metric measure, while there are about 20 different 'libras,' or pounds, in use, ranging from 0.350 kilogram to 0.579 kilogram, each of which is common to its town or province.

35. "The rule generally used in the shops is a many-jointed folding 'metro' of wood, which carries metric and English measures, but there are large numbers sold also of French make, and which carry the French inches in addition to the English and metric. In regard to the change from English to metric measures proposed in the United States and being agitated in England, it surely would be a great pity to throw deliberately away the uniformity at present reigning in those countries. However great may be the theoretical advantage of the metric system, the matter resolves itself entirely into one of use or practice. After four and a half years in a professedly metric country, the English system is still to me

the easier, owing to the greater number of years of practice I have had with it. After some forty or more years of metric system in this country the mixture is, after all these years, an abominable mixture still, and bids fair to continue so for very many years more.

"As evidencing the nuisance now caused, I may quote the following: I recently bought a French lathe, constructed in Paris, and nominally of the latest model. The lead screw is 4 per inch, the gearing cut to Brown & Sharp formula, all outside bolts are English pitch, but the countersunk screws in the saddle are ⅝ diameter by 1½ mm. pitch, which cannot be cut by any combination of gears supplied with the lathe, so that, one being lost, I have either to make a 127-tooth wheel, or get a special screw from the makers of the lathe."

The Persistence of Old Units in Spanish-America.

36. The most recent star example of quick change in weights and measures to which the metric advocates point is Mexico. Mr. Troemner testified (p. 11): "Only recently, within the past two weeks, I talked with the Commissioner of Mines of Mexico, who visited me, and he told me the metric system was working magnificently in Mexico and that they had made the jump at once from one standard to the other."

Following is an extract from a letter from the Superintendent of Machinery of the Mexican Central Railway—Mr. Ben Johnson. The letter is dated at Mexico City, October 7, 1902:

> "We use nothing whatever but American measurements in the work of the mechanical department. Our drawings of locomotives and cars and our shop tools are all in American measurements, and as far as my information goes, this is the case with nearly all railroads in Mexico."

The Mexican Commissioner of Mines has, it is clear, no knowledge of the practice of Mexican railroads. What reason is there for supposing that he has any knowledge of other interests outside his immediate personal experience?

37. In the journal of the Franklin Institute for November, 1902, I find a letter from Mr. R. C. Canby, who has lived in Mexico for four and a half years, where he is in charge of the works of the Montezuma Lead Co., of Santa Barbara, Chihuahua. From this letter I make the following extract:

"About a year ago I was sent by the company to the State of Chihuahua to superintend some new metallurgical operations, and it is surprising to me at this time to see the Babel of standards. The survey of the land upon which the works are built, as well as all levels, are in the metric system. The plans for all buildings and machinery are in the American system. A building so many feet long and so many feet wide is on such and such a metre level. All lumber ordered from Texas or from the mills in the Sierra Madre is ordered so many inches by so many feet in customary United States sizes. Local dealers sell you so many metres of such or such inch pipe, and the bill so reads. All valves and fittings come in inches. Of merchant iron you buy so many kilos of the dimensions given in inches, and I have a list-card from one of the *Mexican manufacturers* of bar and sheet-iron giving the dimensions in $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$ and $\frac{1}{16}$ of an inch, that would suit the most conservative of your correspondents. Obliging salesmen in the stores can always give you the price in 'metros' or 'varas.' Your cordwood has to be converted from 'cargas' and your hay or straw from 'arrobas.'"

38. My friend and former associate in the business of the Rand Drill Company—Mr. V. M. Braschi now and for twelve years in the mining machinery and supply business in the city of Mexico—tells me the same story as that given in Mr. Canby's letter. He sells, for example, so many metres of $\frac{5}{8}$-inch wire rope. The dimension which the merchant measures off, and by which he sets his price is metric, but other dimensions may be in any unit which may be convenient. What a tremendous saving of time in calculations this must lead to!

The metric system of weights and measures became compulsory in Mexico, January 1, 1884.

39. The conditions in Brazil are thus explained by M. de L'Espée, who has already been quoted regarding conditions in France:

"In South America, the progress with the general public has been slower, as could have been expected. In Brazil, a country I know well,* outside of the large cities metric units are in but little use, and the variety of standards is practically unlimited. Most books give such units as vara, etc., which I never saw employed. Those I saw in use are the following:

"Length: The pollegada (inch); the palma (the old French palme of 22 centimeters); the pé (foot); the braca (brasse); the legua (league) of 6,600 metres.

"Area: The alquiere, containing 8 salamis, and varying widely in size from one place to another; it is equal to 2.2 hectares in Minas Geraes.

"Volumes: The alquiere of 33 litres is used for grain, as well as the carro, or load of a bullcart. For liquids, the pipa of some 600 litres, and the cargueiro or mule load, consisting of 2 small barrels of 40 litres each.

"Weights: The arroba of 15 kilos is generally used, to such an extent that the Rio Janeiro Exchange has to mark coffee quotations in arrobas, whereas the

---

* M. de L'Espée lived four years in Brazil.

Santos market gives quotations per 10 kilos. Gold is uniformly sold by the oitava (⅛ oz.)

Following are extracts from a letter by Mr. D. S. Iglehart, of the export house of W. R. Grace & Co. He lived for a time in Peru, and has fortified his recollection of the facts by consulting the Peruvian Consul General:

"I have to-day seen the Peruvian Consul-General, who advises me that the metric system of weights and measures was established as the legal standard in Peru, November 29, 1862.

"As regards the system used in length measurements among merchants, the standard almost universally employed is the vara (.836 metres). This is especially true of the retail trade. Among wholesale merchants the metre is at times employed, as is also our yard. Feet and inches are used in connection with the vara.

"What I have said regarding Peru is more or less true of Chile, although I think that there the metric system is a little more extensively employed."

40. At the Indianapolis (1892) meeting of the National Association of Manufacturers I had a long conversation with Mr. Rudolf Dolge, who, as a representative of that association, has travelled extensively in Europe, China, and Venezuela, in which last country he has lived for four years. He has acted in almost every conceivable commercial capacity for almost every conceivable kind of business, having had charge of the warehouse of the association at Caracas, Venezuela, and his opportunities for observation have thus been unique. His story is the same as that of Mr. Iglehart—in Venezuela the metre is practically unknown, the old vara being the commercial unit of length.* He reports the same condition in China, where he lived for two years. For the claim that the metre is, in any real sense, established as an international unit he has nothing but contempt.

As I read the testimony of Mr. Iglehart and Mr. Dolge, the dry-goods merchants of Peru and Venezuela have not yet changed the tacks upon their counters wherewith they measure ribbon.

For additional facts regarding the persistence of old units in Spanish-America, see the next section. Every Spanish-American country, I believe, appears in the table of that section.

* A letter directed to Mr. Dolge at Caracas has elicited no reply—a fact which I attribute to the disturbed political condition of the country. My recollection of his Indianapolis conversation is, however, entirely clear.

The Persistence of Old Units in Metric Countries Generally.

41. In Special Consular Reports, vol. xvi., issued by the Bureau of Foreign Commerce of the State Department, Washington, I find a table of "Equivalents of Domestic and Foreign Weights and Measures as Established by Law or Custom." Following is an abstract of as much of this table as relates to *non-metric units used in metric countries.**

42. NON-METRIC UNITS USED IN METRIC COUNTRIES.

COMPILED BY THE DEPARTMENT OF STATE, WASHINGTON.

Denominations.	Where used.	American equivalents.
Aam (wine)	Amsterdam	41 gallons.
Aam (oil)	....do	37.73 gallons.
Aam	Antwerp	57.5635 gallons.
Do	Rotterdam	40.559 gallons.
Achtel:		
Dry	Austria	0.2181 bushel.
Solid	Prussia	0.2083 bushel.
Ahm (liquor)	Amsterdam	40.00 gallons.
Do	Hamburg	38.1473 gallons.
Do	Hanover	41.4395 gallons.
Do	Leipsic	40.0769 gallons.
Ahm (liquor)	Lubeck	39.5739 gallons.
Almude	Canary Islands	0.1481 bushel.
Do	Lisbon	4.3697 gallons.
Do	Oporto	6.731 gallons.
Do	Sicily	4.896 gallons.
Aln	Sweden	0.6494 yard.
Alqueire (dry)	Brazil	1.1042 bushels.
Alqueire	Lisbon	2.1848 gallons.
Alqueire (dry)	....do	0.3837 bushel.
Alqueire	Oporto	3.3128 gallons.
Do	Portugal	2.1848 gallons.
Alqueire (dry)	....do	4.75 bushels.
Am or ahm	Sweden	41.4432 bushels.
Amola	Genoa	0.2175 bushel.
Anker	Amsterdam	10.25 gallons.
Do	Hamburg	9.5368 gallons.
Do	Riga	10.333 gallons.
Do	Rostock	9.562 gallons.
Do	Rotterdam	10.1392 gallons.
Do	Sweden	13.3608 gallons.
Do	Alexandria	7.6907 bushels.
Do	Cairo	5.1649 bushels.

* Examination of this table will show that strict accuracy in the selections is not easy. Owing to this difficulty, I have endeavored to resolve all doubts in favor of the metric system and following this policy have omitted all Russian and Danish units. In spite of this policy it is possible that the table may contain a few units which should have been excluded; but for every such unit there are not less than three which belong in the table, but which because of the above named policy have been excluded. The reader will note the numerous German units.

NON-METRIC UNITS USED IN METRIC COUNTRIES—*Continued.*

Denominations.	Where used.	American equivalents.
Arratel	Brazil	1.019 pounds.
Do	Portugal	1.012 pounds.
Arroba	Argentina	25.32 pounds.
Do	Bolivia	25.3537 pounds.
Do	Brazil	32.38 pounds.
Do	Buenos Ayres	25.36 pounds.
Do	Canary Islands	4.245 gallons.
Do	Cuba	25.4375 pounds.
Do	....do	4.1 gallons.
Do	Mexico	25.365 pounds.
Do	Chile	25.365 pounds.
Do	Portugal	32.38 pounds.
Do	Spain	25.36 pounds.
Do	....do	4.2630 gallons.
Arsin	Hungary	0.6392 yard.
Aune	Basel	1.2833 yards.
Do	Belgium	0.7611 yard.
Do	France	1.25 yards.
Do	Geneva	1.25 yards.
Bambou	Madagascar	0.0576 bushel.
Barile	Argentina	20.0768 gallons.
Barile (oil)	Genoa	17,0835 gallons.
Barile (wine)	....do	19.61 gallons.
Barile	Malta	11 gallons.
Do	Mexico	20 gallons.
Do	Naples	11.5732 gallons.
Barril (honey)	Havana	6 gallons.
Barril	Lisbon	78.655 gallons.
Barril (raisins)	Malaga	50.6 pounds.
Barique (wine)	Bordeaux	60 gallons.
Do	Nantes	63.405 gallons.
Do	Rochelle	46.04 gallons.
Batman	....	....
Do	Constantinople	19.132 pounds.
Boccale	Bologna	0.346 gallon.
Do	Leghorn	0.301 gallon.
Do	Milan	0.208 gallon.
Do	Venice	0.267 gallon.
Bota	Portugal	113.631 gallons.
Do	Spain	127.89 gallons.
Botta	Messina	108 gallons.
Do	Naples	128.879 gallons.
Do	Rome	246.6 gallons.
Box:		
Raisins	Malaga	44 pounds.
Do	Deiaa and Valencia	56 pounds.
Braccio	Basel	0.5951 yard.
Do	Leghorn	0.6383 yard.
Do	Milan	1.0936 yards.
Caban:		
Cocoa	Manila	83.50 pounds.
Rice	....do	133 pounds.
Canada	Bahia	1.8727 gallons.
Do	Rio Janeiro	0.3641 gallon.
Canna	Genoa	2.4518 yards.
Do	Leghorn	2.553 yards.
Do	Messina	2.3111 yards.

NON-METRIC UNITS USED IN METRIC COUNTRIES—*Continued.*

Denominations.	Where used.	American equivalents.
Cantara (maximum)	Spain	4.8714 gallons.
Cantara (mean)	do	3,3753 gallons.
Cantaro	Cairo	95.0312 pounds.
Do	Constantinople	140.3008 pounds.
Do	Cuba	4.1 gallons.
Cantaro (grosso)	Genoa	115.31 pounds.
Cantaro (sottile)	do	104.83 pounds.
Carga (raisins)	Malaga	177.5 pounds.
Carga (raisins)	Valencia	338.44 pounds.
Carga (wine)	Barcelona	31.8493 gallons.
Carga (oil)	do	32.6524 gallons.
Carrata:		
Marble	Carrara	2,240 pounds.
Solid	do	7.1268 cubic feet.
Carreau (stone)	France	3.632 cubic feet.
Carro (dry)	Naples	56.3258 bushels.
Do	do	257.757 gallons.
Catty	China	1.3333 pounds.
Do	Japan	1.3085 pounds.
Do	Java	1.356 pounds.
Cavezzo	Florence	3.8257 yards.
Do.	Venice	2.2818 yards.
Centner	Bremen	127.5 pounds.
Do	Norway	110.11 pounds.
Do	Nurnberg	112.43 pounds.
Do	Prussia	113.44 pounds.
Do	Sweden	112.512 pounds.
Do	Vienna	123.4677 pounds.
Chenng	Canton	4.1007 yards.
Do	Pekin	3.6458 yards.
Chik or Chih	China	0.3917 yard.
Corba	Bologna	20.7618 gallons.
Dry	do	2.2317 bushels.
Coupe	Geneva	2.2036 bushels.
Covid		
Do	China	0.3907 yard.
Do	Java	0.75 yard.
Cubic foot (marble)	Carrara	185 pounds.
Cubic foot (onyx)	Mexico	215 pounds.
Cubic palmo (marble)	Italy	0.555 cubic foot.
Derah	Cairo	0.708 yard.
Dirhem		
Do	Constantinople	49.5 grains.
Drachma	Cairo	48.6 grains.
Do	Hungary	48.62 grains.
Do	Vienna	67.69 grains.
Dragma	Amsterdam	59.32 grains.
Dreiling	Vienna	448.5741 gallons.
Duim	Holland	1.094 yards.
Eimer	Austria	14.9526 gallons.
Eimer (beer)	Bavaria	18.0751 gallons.
Eimer (wine)	Bavaria	16.9444 gallons.
Eimer	Berlin	18.1464 gallons.
Do	Hamburg	7.6295 gallons.
Do	Leipsic	20.0384 gallons.
Do	Nurnberg	18.2233 gallons.
Do	Prague	16.9515 gallons.

NON-METRIC UNITS USED IN METRIC COUNTRIES—*Continued.*

Denominations.	Where used.	American equivalents.
Eimer	Rostock	7.6506 gallons.
Eimer (lauter-mass)	Zurich	28.9275 gallons.
Eimer (trüber-mass)	....do	30.866 gallons.
Ell	Holland	1.094 yards.
Elle	Austria	0.8522 yard.
Do	Basel	1.2337 yards.
Do	Bavaria	0.911 yard.
Do	Berlin	0.7293 yard.
Do	Bremen	0.6438 yard.
Do	Dresden	0.6196 yard.
Do	Frankfort-on-the-Main	0.5986 yard.
Elle (silk)	Hamburg	0.6266 yard.
Elle (wool)	....do	0.7562 yard.
Elle	Munich	0.911 yard.
Do	Prague	0.6496 yard.
Do	Rostock	0.6325 yard.
Do	Zurich	0.6563 yard.
Embar	Sweden	20.7327 gallons.
Emmer	Antwerp	8.8059 gallons.
Estado	Spain	1.8547 yards.
Fanega	Buenos Ayres	3.75 bushels.
Do	Chile	2.838 bushels.
Do	Havana	3.1102 bushels.
Do	Maderia	1.601 bushels.
Do	Mexico	1.5473 gallons.
Do	Montevideo	3.868 gallons.
Do	Spain	1.5753 bushels.
Do	Valparaiso	2.5753 bushels.
Fanga	Azores Islands	1.36 bushels.
Do	Lisbon	1.5347 bushels.
Do	Oporto	1.9374 bushels.
Do	Rio Janeiro	1.5347 bushels.
Fass	Berlin	60.497 gallons.
Do	Bohemia	64.56 gallons.
Fass (oil)	Hamburg	38.2556 gallons.
Fass (dry)	....do	1.4941 bushels.
Fass (wine)	Leipzig	100.1737 gallons.
Fass (beer)	....do	95.4052 gallons.
Fass	Prague	67.806 gallons.
Fass (dry)	Rostock	0.2758 bushel.
Fass (wine)	Vienna	153.2629 gallons.
Fass (beer)	....do	31.7727 gallons.
Fjerding	Finland	8.2931 gallons.
Do	Sweden	8.29 gallons.
Fjerding (dry)	....do	0.5196 bushel.
Fot	Sweden	0.9714 foot.
Frasco	Brazil	0.5625 gallon.
Fuder	Berlin	217.7883 gallons.
Do	Copenhagen	237.3375 gallons.
Do	Frankfort-on-the-Main	227.3462 gallons.
Do	Hamburg	229.7791 gallons.
Do	Leipzig	240.4612 gallons.
Do	Rostock	229.5178 gallons.
Do	Sweden	258.8028 gallons.
Do	Vienna	478.479 bushels.
Fuss	Antwerp	0.3123 yard.
Do	Berlin	0.3432 yard.

NON-METRIC UNITS USED IN METRIC COUNTRIES—*Continued.*

Denominations.	Where used.	American equivalents.
Fuss	Bremen	0.3163 yard.
Do	Frankfort	0.3113 yard.
Do	Hamburg	0.3133 yard.
Do	Hungary	0.3457 yard.
Do	Munich	0.3192 yard.
Do	Vienna	0.3457 yard.
Hok (dry)	China	1.0887 bushels.
Ikje	Japan	2.3165 yards.
Ink	Japan	2.0785 yards.
Kan	China	1.3333 pounds.
Do	Holland	0.2642 gallon.
Kande	Norway	0.5104 gallon.
Kanne	Batavia	0.3939 gallon.
Do	Hamburg	0.4782 gallon.
Do	Leipzig	0.3181 gallon.
Do	Rostock	0.4349 gallon.
Kanne (butter)	Saxony	24.7344 pounds.
Kanne	Vienna	0.1873 gallon.
Kasten	Wurtemberg	4.0047 bushels.
Knital	Constantinople	124.564 pounds.
Klafter	Basel	1.2893 yards.
Klafter (solid)	Basle	128 cubic feet.
Klafter	Berlin	2.0595 yards.
Klafter (solid)	....do	117.907 cubic feet.
Klafter	Bremen	189.77 yards.
Do	Hamburg	1.8799 yards.
Do	Leipzig	1.8547 yards.
Klafter (solid)	....do	100.49 cubic feet.
Klafter	Vienna	2.0742 yards.
Do	Wurtemberg	1.88 yards.
Klafter (solid)	....do	119.583 cubic feet.
Kong-pu	China	0.3347 yard.
Kopf	Zurich	0.9643 gallon.
Korb	Zurich	10.538 bushels.
Kumme	Berlin	26.841 cubic feet.
Kwan	China	40 pounds.
Lagel (steel)	Prussia	103.1156 pounds.
Landfass	Berne	264.971 gallons.
Last	Amsterdam	85.2457 pounds.
Last	Bremen	329.718 pounds.
Last (dry)	....do	84.078 bushels.
Last	Hamburg	89.8163 bushels.
Do	Prussia	112.292 bushels.
Lastre	Argentina	58.404 bushels.
Legger (arrack)	Amsterdam	153.752 gallons.
Do	Batavia	160 gallons.
Leung	China	0.0833 pound.
Libbra	Bologna	0.7984 pound.
Libbra (old)	Italy	0.8146 pound.
Libra	Chile	1.0141 pounds.
Do	Cuba	1.0161 pounds.
Do	Mexico	1.01465 pounds.
Do	Peru	1.0143 pounds.
Do	Spain	1.0143 pounds.
Do	United States of Colombia	1.0143 pounds.
Do	Uruguay	1.0143 pounds.
Do	Venezuela	1.0143 pounds.

NON-METRIC UNITS USED IN METRIC COUNTRIES—*Continued.*

Denominations.	Where used.	American equivalents.
Libra	Porto Rico	1.0161 pounds.
Lispund	Norway	17.6158 pounds.
Lispund (metal)	Sweden	14.9965 pounds.
Lispund (viktualie)	....do	18.7457 pounds.
Litra	Greece	0.2642 gallon.
Livre	Antwerp	1.037 pounds.
Do	Bordeaux	1.1024 pounds.
Do	Brussels	1.0311 pounds.
Do	Geneva	1.2142 pounds.
Livre (silk)	Lyons	1.0118 pounds.
Maas	Austria	0.373 gallon.
Do	Bavaria	0.2824 gallon.
Maat (salt)	Amsterdam	1.745 bushels.
Mallal	Barcelona	3.9812 gallons.
Malter	Baden	4.2567 gallons.
Do	Prussia	18.7164 bushels.
Do	Zurich	9.4416 bushels.
Mass	Austria	0.373 gallon.
Do	Bavaria	0.2824 gallon.
Medida	Brazil	0.7331 gallon.
Metical	Constantinople	74.25 grains.
Metze	Austria	1.7454 bushels.
Do	Hungary	1.774 bushels.
Mezzaruola	Genoa	39.2172 gallons.
Mina	Genoa	3.4257 bushels.
Do	Greece	2.2046 pounds.
Do	Milan	2.6418 gallons.
Moggio	Venice	9.081 bushels.
Moio	Lisbon	23.0202 bushels.
Monkelzer	Persia	0.7836 yard.
Monme	Japan	3.750 grammes.
Mudde	Holland	2.8378 bushels.
Muid	French Guiana	70.8552 gallons.
Do	Brussels	8.032 bushels.
Do	Paris	53.1579 bushels.
Mutt	St. Gall	2.344 bushels.
Do	Zurich	2.3304 bushels.
Ocquich	Cairo	0.1504 ounce.
Ohm	Baden	39.6267 gallons.
Do	Basel	13.4459 gallons.
Do	Berlin	49.8197 gallons.
Do	Bremen	38.2965 gallons.
Do	Frankfort	37.891 gallons.
Do	Lubeck	38.4394 gallons.
Oka	Cairo	2.7771 pounds.
Do	Constantinople	2.8342 pounds.
Do	Egypt	2.7235 pounds.
Do	Greece	3.3714 pounds.
Do	Hungary	3.0817 pounds.
Orcio (oil)	Florence	8.8315 gallons.
Ottingkar	Finland	4.1476 gallons.
Outava (precious stones)	Brazil	0.1307 ounce.
Oxhoft	Berlin	54.4391 gallons.
Do	Dresden	53.43 gallons.
Do	Hamburg	57.221 gallons.
Do	Hanover	62.1593 gallons.
Oxhoft (brandy)	Leipsic	60.1153 gallons.

NON-METRIC UNITS USED IN METRIC COUNTRIES—*Continued.*

Denominations.	Where used.	American equivalents.
Oxhoft (wine)	....do	53.4358 gallons.
Oxhoft	Rostock	57.3822 gallons.
Oxhufwud	Sweden	62.1980 gallons.
Palme	Belgium	3.937 inches.
Palmo	Brazil	8.5592 inches.
Palmo (marble)	Carrara	9.592 inches.
Palmo	Leghorn	11.4884 inches.
Pecul	China	133.3333 pounds.
Do	Japan	130 pounds.
Do	Malacca	135 pounds.
Do	Manila	140 pounds.
Pfund	Austria	1.2347 pounds.
Do	Baden	1.1024 pounds.
Do	Basel	1.0792 pounds.
Do	Bavaria	1.2347 pounds.
Do	Berlin	1.0312 pounds.
Do	Bremen	1.0991 pounds.
Do	Brunswick	1.0296 pounds.
Do	Frankfurt	1.1141 pounds.
Pfund (zoll)	Germany	1.1025 pounds.
Pfund	Hamburg	1.0679 pounds.
Do	Hanover	1.0794 pounds.
Do	Leipsic	1.0306 pounds.
Do	Prussia	1.0312 pounds.
Do	Rostock	1.1205 pounds.
Do	Vienna	1.2347 pounds.
Do	Zurich	1.1651 pounds.
Pfundschwer	Bremen	329.57 pounds.
Do	Cairo	0.7404 yard.
Do	Constantinople	0.7317 yard.
Pié	Argentina	0.3159 yard.
Do	Cuba	0.3091 yard.
Do	Curaçao	0.3090 yard.
Do	Mexico	0.3091 yard.
Do	Spain	0.3091 yard.
Do	Venice	0.3803 yard.
Ping	China	17.4186 bushels.
Pipa	Canary Islands	120 gallons.
Do	Lisbon	135 gallons.
Do	Madeira	110 gallons.
Do	Rio Janeiro	132.089 gallons.
Do	Sweden	124.3961 gallons.
Pipe (brandy)	Bordeaux	99.5951 gallons.
Do	Cognac	152.7821 gallons.
Pond (Brabant)	Amsterdam	1.0371 pounds.
Pond (Troy)	....do	1.0847 pounds.
Pot	Antwerp	0.363 gallon.
Pot (beer)	Brussels	0.3435 gallon.
Pot (wine)	....do	0.3578 gallon.
Pott	Basel	0.1051 gallon.
Do	Denmark	0.2552 gallon.
Do	Norway	0.2552 gallon.
Quardeel (oil)	Amsterdam	98.1421 gallons.
Quarto (oil)	Genoa	4.2709 gallons.
Quene	Burgundy	106.2841 gallons.
Quilate (precious stones)	Brazil	3.075 grains.
Quintal	Argentina	101.27 pounds.

NON-METRIC UNITS USED IN METRIC COUNTRIES—*Continued.*

Denominations.	Where used.	American equivalents.
Quintal	Brazil	130.0604 pounds.
Do	Chile	101.6097 pounds.
Do	Mexico	101.6097 pounds.
Do	Peru	101.6097 pounds.
Do	Spain	101.6097 pounds.
Do	Valencia	109.7285 pounds.
Raza (salt)	Oporto	1.2509 bushels.
Raziere	Antwerp	2.2597 bushels.
Rebeb	Alexandria	4.4582 bushels.
Rjoo	Japan	0.1659 pound.
Rotl	Cairo	0.9804 pound.
Rottel	Turkey	1.247 pounds.
Rubbio	Leghorn	7.7767 bushels.
Do	Rome	8.3553 bushels.
Ruthe	Bavaria	3.1919 yards.
Do	Bremen	5.0604 yards.
Do	Leipsic	4.946 yards.
Do	Prussia	4.119 yards.
Do	Zurich	3.296 yards.
Do	Geneva	2.204 bushels.
Sac (wheat and flour)	Paris	5.9987 bushels.
Sacco	Leghorn	2.0746 bushels.
Do	Milan	4.151 bushels.
Do	Nice	3.4054 bushels.
Do	Turin	3.2635 bushels.
Sack	Basel	3.8781 bushels.
Salma	Naples	40.2726 gallons.
Salma (oil)	....do	42.1667 gallons.
Salma (wine)	Sicily	22 gallons.
Salma (dry)	....do	7.8 bushels.
Salma (grosso)	....do	10 bushels.
Sals	Japan	0.3314 yard.
Saum	Austria	275 pounds.
Do	Basel	40.3377 gallons.
Do	St. Gall	44.371 gallons.
Do	Switzerland	441.8293 pounds.
Do	Vienna	339.5357 pounds.
Scheffel	Bavaria	6.31 bushels.
Do	Bremen	2.102 bushels.
Do	Dresden	2.9485 bushels.
Do	Hamburg	2.9884 bushels.
Scheffel (barley)	....do	4.4823 bushels.
Scheffel	Leipsic	2.9485 bushels.
Do	Prussia	1.5597 bushels.
Do	Weimar	2.1841 bushels.
Do	Wurttemberg	5.0292 bushels.
Schepel	Holland	0.2838 bushel.
Schifflast	Berlin	4,124.72 pounds.
Schiffpfund	....do	340.4114 pounds
Do	Bremen	318.7274 pounds.
Do	Hamburg	299.0082 pounds.
Schippond	Amsterdam	326.742 pounds.
Do	Antwerp	310.974 pounds.
Schoppen	Basel	0.0991 gallon.
Do	Frankfort	0.1184 gallon.
Schragen	Leipsic	301.47 cubic feet.
Schuh	Basel	0.331 yard.

NON-METRIC UNITS USED IN METRIC COUNTRIES—*Continued.*

Denominations.	Where used.	American equivalents.
Sei	China	3.4716 bushels.
Sextingkar	Finland	2.0733 gallons.
Shik:		
Tsong	China	160 pounds.
Shi	do	2.1773 bushels.
Sjoo	Japan	0.4591 gallon.
Skalpund	Sweden	0.9361 pound.
Skeppund:		
Metal	do	299.931 pounds.
Viktualie	do	374.9136 pounds.
Stab	Frankfort	1.3124 yards.
Do	Hungary	1.7285 yards.
Do	Leipsic	1.2365 yards.
Do	St. Gall	1.3124 yards.
Stajo	Leghorn	0.6916 bushel.
Stajo or staro	Naples	2.6163 gallons.
Stang	Sweden	5.181 yards.
Steekan	Amsterdam	5.1251 gallons.
Stein	Berlin	22.686 pounds.
Stein (flax)	Bremen	21.9812 pounds.
Do	Hamburg	21.3577 pounds.
Do	Rostock	24.65 pounds.
Stein	Vienna	24.65 pounds.
Sten	Sweden	29.993 pounds.
Stop	Sweden	0.3454 gallon.
Strich	Prague	2.6562 bushels.
Stückfass	Frankfort	303.1283 gallons.
Stütz	Neufchatel	4.0246 gallons.
Talanton	Greece	330.607 pounds.
Tam	China	133.3333 pounds.
Tass (figs)	Portugal	33 pounds.
Tercio (tobacco)	Cuba	160 pounds.
Tomolo	Naples	1.5646 bushels.
Tonelada	Argentina	29.202 bushels.
Tonne (beer)	Berlin	30.2484 gallons.
Do	Bremen	43.8361 gallons.
Do	Germany	2,204.6212 pounds.
Do	Hamburg	45.7771 gallons.
Do	Rostock	30.6192 gallons.
Tun (oil)	Malaga	2.233 pounds.
Tunna	Sweden	33.1596 gallons.
Dry	do	4.1571 gallons.
Uper	Belgium	0.9075 gallon.
Urna	Hungary	14.3053 gallons.
Vaam	Holland	2.0594 yards.
Vara	Argentina	0.9478 yard.
Do	Chile	0.9164 yard.
Do	Cuba	0.9271 yard.
Do	Mexico	0.9139 yard.
Do	Peru	0.9164 yard.
Do	Portugal	1.203 yards.
Do	Spain	0.9141 yard.
Do	Venezuela	0.9141 yard.
Velt	Antwerp	2 gallons.
Velt (brandy)	France	2 gallons.
Velt	Paris	1.9683 gallons.
Viertel	Amsterdam	1.9524 gallons.

NON-METRIC UNITS USED IN METRIC COUNTRIES—*Continued.*

Denominations.	Where used.	American equivalents.
Viertel	Basel	1.5028 gallons.
Do	Bremen	1.9148 gallons.
Do	Hamburg	1.9074 gallons.
Do	Rostock	1.9137 gallons.
Viertel (beer)	....do	7.6548 gallons.
Viertel	Vienna	3,7361 gallons.
Wispel (rye)	Hamburg	29.8811 bushels.
Yin	China	2.6667 pounds.
Zak	Holland	2.8378 bushels.

43. Regarding the use of these units and of this table, I quote as follows from three letters from Mr. Emory, Chief of the Bureau of Foreign Commerce, whose opportunity for obtaining information on this subject is unique.

It [the table] is in daily use in this Bureau in the reduction of foreign weights and measures to United States equivalents.

While the metric system is legal in the countries you mention [my reference was to metric countries in general], the old units are also very widely used. In the statements of imports and exports, the metric system is commonly employed; in business transactions in the interior, the other units.

In South American countries especially, although the metric system has been introduced and is in use for customs transactions, the non-metric units, native to the countries, are often employed in domestic transactions. These units frequently appear in the reports of Consular Officers, and I will mention a few.

The Spanish or Castilian quintal of 101.61 pounds is used in Chile (Commercial Relations, 1900, vol. i., p. 789); the measure "zeroons" (meaning unknown) occurs in the same volume, p 823; the arroba, the cuadra, and the lino are used in Paraguay (Commercial Relations, 1899, vol. i., page 687), meaning 10,000 square yards, 25 pounds, and 100 yards, respectively. The quintal in Guatemala, in the export of coffee, is "about 100 pounds" (Commercial Relations, 1898, volume i., p. 650); the finca is used in Costa Rica to designate "any area of land" (Commercial Relations, 1896–97, p. 531). The cantar is employed in Sicily in the export of sulphur; it is equivalent to 175 pounds (Commercial Relations, 1901, vol. ii., p. 429). These are only some instances that I happen to recall; a search through the Consular Reports would show many others. See also the Statesman's Year Book, 1902, p. 481: "The French metric system . . . is used in official departments (in Brazil), but the ancient weights and measures are still partly employed. They are the libra, the arroba, the quintal, etc." Page 492: "The metric system is legally established in Chile since 1865, but the old Spanish weights and measures are still in use to some extent." Page 517: "The metric system was introduced into the Republic (of Colombia) in 1857; in custom house business, the kilogramme . . . is the standard; in ordinary commerce the arroba, carga, etc., are generally used." These quotations could be multiplied. I send you copies of the Commercial Relations, above referred to, and would repeat that an examination of the volumes will show other instances of the use of native weights and measures.

44. Mr. Colvin has made a further examination of Consular Relations as suggested by Mr. Emory, with the result which he has given in the discussion.

Additional facts regarding the use of old units in metric countries are given in the following letter from the Collector of the Port of New York.

I have to state that this office is in receipt of a large number of invoices received from France, wherein the measurements of the textile fabrics covered by said invoices are expressed in aunes, and also from Switzerland covering embroideries wherein the measurements are expressed in aunes.

I have caused to be taken from the files of this office a number of invoices from Spain, Italy, Holland and Belgium, and find as follows: From Spain, 233 invoices, thirty-seven of which the weights are expressed therein as pounds, the remainder being made out according to the metric system; from Italy, fifteen invoices, the weights therein expressed in the metric system; from Holland, fifty-five invoices, fourteen of which the weights are expressed therein as pounds; eleven of the fourteen are expressed as pounds avoirdupois, and the other three invoices not stating the kind of pound, the remainder of the invoices being made out according to the metric system; from Belgium, one hundred and twenty-six invoices, fourteen of which the weights are expressed in pounds, thirty-one in feet or inches, two in yards and one in gallons, the remainder being made out according to the metric system.

In conclusion, I have to state that in many of the invoices received at this office from countries in South America, the weights are made out in the old Spanish pound.

45. It will be observed that the letters of Messrs. Ball and Emory and Collector Stranahan relate chiefly to the commercial use of old units, although this is much more restricted than their factory use, as is shown by the fact that the fabrics which are made in the mills of Lyons by the aune are sold across the shop counters of Paris by the metre. Until late in this inquiry I had supposed the metre to be really established in European commerce, though not in manufacture. These letters show that even in commerce it is by no means universal.

The fatal mistake of the metric advocates and the weakness of their case lies in their assumption that the statute book is an index of the practice of the people.

The arguments for the saving of time in calculation, for the simplification of our weights and measures and for the saving of time by school children are all based on the tacit assumption that the old units are to disappear. As they have not done so elsewhere they will not do so here, and every one of these arguments falls to the ground. The whole metric case is riven into shreds by the simple fact that these old units will not die.

Shall we carry our heads in the clouds of speculation, or shall we consult the experience of others? Shall we join in the chase of this will-o'-the-wisp which no nation has ever caught? That and that only is the metric question of the hour. Arguments based on the "beautiful interrelation and correlation of the units" have little more application than a philosophical speculation regarding the appearance of the back side of the moon.

Reasons for the Length of the Transition Period.

46. An essential feature of the scientific method is the explanation of the facts as found, and it is easy to show why the period of transition must be so long. The pamphlet containing this testimony before the House committee contains a letter from the Brown & Sharpe Manufacturing Company, which contains a sentence embodying more wisdom and knowledge of the subject than all the pro-metric testimony. I quote (page 190): "The question of weights deals rather with the future, but . . . linear measures are tied irrevocably to the past." The man who wrote that sentence was inspired, and for a time it will become my text.

47. If this system were made compulsory to-morrow, and the people were to receive it with enthusiasm, the gas pipes in the ceilings of our homes alone would keep the old system alive for fifty years. Remember the proof that has been given that the metric system necessitates metric sizes. Now make the gas tips which we replace so often with metric threads, and there isn't a chandelier in this country that will take them. Make the chandeliers with metric threads, and there isn't a gas pipe end projecting from a single ceiling in this country which will take them. A fair question to ask here is, how long does it take on the average for a gas pipe to wear out? Our friends tell us that for a time we will use transition fittings with English threads at one end and metric threads at the other, but this begs the whole question. The transition fittings must be made. The length of the pipe does not alter the thread or the tools for making it The tools and the equipment must be preserved. But why make a transition fitting at extra cost and serving no purpose except to furnish an added joint to leak? We may be sure that so long as pipes with English threads endure in our ceilings, chandeliers will be made

with English threads to fit them. Why is this? Because "measures of length are tied irrevocably to the past."

48. Every factory contains overhead lines of shafting which with the pulleys to fit are a standardized line of manufacture. With standard fits pulleys may be changed from place to place by simply removing and replacing. Put up a metric line shaft, and not a pulley in this country will fit it, nor will any metric pulley fit an English line shaft. A line of shafting was scarcely ever known to wear out. I know one which is forty years old, and it was, I believe, second-hand when I made its acquaintance. So long as existing shafts endure we may be sure English dimension pulleys will be made to fit them. Why? Again, because "measures of length are tied irrevocably to the past."

49. They tell us that we may continue to use the old units in repairs. Consider the couplings which connect the air-brake hose on all railroad cars. A new coupling on one car connects with the old one on another car. The time will never come when that can be changed, unless they are all changed at once. Why? Because "measures of length are tied irrevocably to the past."

At the hearings of the House committee a curious fact was developed (Mr. Buck, page 145). The older part of Philadelphia was laid out by a defective surveyor's chain which, instead of being 100 feet long, was in reality 100 feet 3 inches, and in that part of the city to-day 100 feet 3 inches is legally 100 feet. By a curious process of reasoning this was made to appear as an argument for the metric system, though how the adoption of that system is to change the layout of the streets I do not quite see. Why does this anomaly, this nuisance, persist, and why is it impossible to get rid of it? Because "measures of length are tied irrevocably to the past."

The Adoption of the Metric System Necessitates Abandoning Mechanical Standards.

50. The metric advocates tell us that it is not necessary, nor is it desired to destroy our existing standards, and the report of the House committee contains these naïve words: "This measure in no way contemplates any change in existing technical standards, such as screw threads, wire gauges, lumber measures, and numerous others, except as manufacturers and other interests find it to their common interest to make the change."

This programme simply contemplates the use, side by side, for an indefinite period, of the inch and the millimetre. Mr. Hess, who has unexcelled opportunities for judging, has already told us that "this is too illogical an arrangement to maintain itself." The desirability of using inches and millimetres side by side need not, however, be left to any one's opinion, as the facts are available for applying the scientific method.

If the use of inches for screw threads and millimetres for general purposes is such a satisfactory plan, why do the nations of Continental Europe make such efforts to establish a metric standard, as is shown in the following quotation from the article by Mr. Hess already referred to as published in the *American Machinist* for May 3, 1900?

> Finally various engineering societies took up the matter and appointed delegates to draw up and sift proposals. The work occupied a number of years, and in the fall of 1898 culminated in the adoption by a congress of delegates from Germany, France, Switzerland, Italy, and other countries using the metric system of measurements, of a shape of thread and pitch to which they assigned the name of Systeme International, generally known by the abbreviation S. I. or S. J.

51. The effort made is a measure of the need of metric threads to go with metric measurements in general. The need here will be as great as in Germany, and we may thus learn that whatever the intentions of those who conduct this metric propaganda may be, the abandonment of the inch does involve the destruction of existing standards, and this illustration is especially fortunate in that it relates to screw threads, a change of which is expressly disclaimed by the House committee. It should be clear to any one that the permanent use of both systems, side by side, is simply unthinkable, and that so long as both systems are in use matters will not be simplified, but complicated.

With characteristic inverted logic, we are told that Germany does not use metric screw threads because she does not need them (Mr. Christie, page 7). On the contrary, the need is shown by the effort put forth; the lack of accomplishment is a measure of the difficulties encountered. Germany fails to use metric screw threads, *not because she does not need them, but because, with all her effort, she cannot get them.* Her continued use of English pitch threads is but another illustration of the difficulty of changing a unit of length and of the length of the period of transition—that period which, I will again remind the reader, the metric advocates assure us will, with us, occupy but three to five years.

52. With one breath these gentlemen tell us how quickly we can make this change and in the next they point with pride to the fact that Germany has not yet changed her screw threads, and yet they have to be told that the second statement stultifies the first.

Is it not supremely absurd to deliberately adopt, *in the name of reform and of simplicity,* a course which will lead to all dimensions of a shaft or spindle, for example, being given in millimetres, except the screw threads, which are to be given in inches? Some of the metric advocates even regard this as a satisfactory permanent plan. Thus Mr. Christie (page 7) says: "We can retain our present standard of screw threads indefinitely even if the metric system is universally used."

Unless, however, this metric programme contemplates the ultimate disappearance of the inch and the substitution therefor of the millimetre, then it is meaningless and purposeless, and I venture to say that if even the House committee really supposed that the only intention of this measure is to add another set of units without getting rid of the old ones, they would have unhesitatingly killed the bill. That, however, has been the effect in France and Germany, and, according to the House committee's report, that only is its purpose here. Proposing to change some things and not others begs the whole question. The proposal to make the easy changes but not the difficult ones, is a tacit acknowledgment that some of the changes are too difficult to make, which is exactly the anti-metric position, and pretty much the whole of it. To suggest that we make the easy changes but not the difficult ones is to surrender the whole case.

53. Another point which may be learned from these quotations from Mr. Hess relates to a suggestion which is constantly made that we continue to use our present sizes, especially of standards, but give metric equivalents for the present English dimensions. It is easy to prove this to be impracticable, but such proof would, necessarily be inductive, which is contrary to my present method.*

* At the beginning of the preparation of this argument I determined to eschew all inductive reasoning and to rely absolutely upon the experimental method, and, following this plan, the words of the text were written. Regarding the present point, I yield, however, to the judgment of Mr. Towne, and give the proof. For this it is only necessary to construct a table of metric equivalents of the usual fractional dimensions, thus:

34. Reverting, then, to the experimental method, though in this case, to prove a negative, I will ask: If the difficulties can be solved so easily by following this plan, why do not the Germans do it? They have many times as many reasons for doing it that we would have, because the millimetre would, if this plan were feasible, form a universal unit for all their numbers as inches, and all

Inches.	Metric Equivalent.	Inches.	Metric Equivalent.
1	25.4	2	50.8
1⅛	28.57	2⅛	53.97
1¼	31.75	2¼	57.15
1⅜	34.92	2⅜	60.32
1½	38.10	2½	63.5
1⅝	41.27	2⅝	66.67
1¾	44.45	2¾	69.85
1⅞	47.62	2⅞	73.02
		3	76.2

Is not the point obvious at a glance? While the law of the series is simple enough, it is not obvious to the eye, and *the man does not live who can memorize the list.* Only two inches of the range are given, and even then only to eighths; but remember that no combination of figures repeats itself until 10 inches is reached, while there is nothing in the above list to correspond to any even inch between 10 and 20 except 15, nor between 20 and 30 except 25. The load which such a table places upon the memory is limited only by its length.

Imagine this table to be a bolt list. A farmer has broken a 28.6 millimetre bolt and wants a larger one, but *he nor anyone can tell what size to call for without calculation or consulting a list.* Are we all to carry a list of bolt sizes in our pockets? Will some one point out the gain due to calling a 1⅛-inch bolt a 28.6 millimetre bolt, or give any reason which should lead any one to use the metric figures?

In a certain stock-room the interval between the sizes of bar iron carried is ⅛ inch. Two of the sizes in stock are 2½ and 2⅝ inches. The metric equivalent of the former is 63.4 millimetres. Will some metric enthusiast, without calculation, kindly name the next metric size? Will he name *any* metric size upon the list except those corresponding to even inches? Will he say if he ever expects to be able to name one-quarter of the sizes used in every tool and stock room? If he thinks he can memorize the table as given, does he think he could do it after the sixteenths are added? If he does, how will the matter stand after the table is extended to, say, ten inches? If he finally gives up the task of memorizing the table, will he say if he intends to carry a list of equivalents in his pocket, or, failing that, whether he expects to use a lead-pencil or a slide rule whenever he has occasion to call for a tool or a bar of iron? *He must do one or the other, or else use the English figures.* Do the metric enthusiasts really think that during the "transition period" any one will calculate metric dimensions which cannot be memorized when he can use English dimensions which memorize themselves?

If the intervals were, say, one millimetre up to 50 mm., two from 50 to 100 and so on, a metric list of sizes could be memorized as easily as our own, but with the their difficulties would vanish. Is it not certain they would do it if they could, and is it not certain they do not do it because they cannot? Again, if this plan is feasible, why do they move heaven and earth in their efforts to establish a metric system of screw threads? If this plan of using metric equivalents for diameters and pitches of English threads is so obvious and so satisfactory, why do they not do it instead of throwing the Whitworth system aside and starting a new one? Again, I say they do not do it because they cannot do it. If they cannot do it we cannot do it, and we may be very sure that if the metric system leads to metric screw threads in Germany it will do so here, and, as will be shown presently, *that is what the leaders of this movement expect.*

55. I do not, of course, wish to be understood as trying to prove that the use of metric equivalents for English sizes is physically impossble. Very possibly it can be shown that the German people, *who have this thing on their hands and must get along with it in some way*, use equivalents in a limited way and in special cases. The habitual use of sizes, of which the list cannot be memorized

---

intervals determined by the English scale it is hopeless to try to memorize the metric equivalents. If they cannot be memorized they will not be used, and this is the end of the metric equivalent scheme.

All plans for saving existing standards depend upon the continued use of the inch or upon the use of metric equivalents. The latter plan being impracticable, it follows that *the abandonment of the inch involves the abandonment of all existing mechanical standards.* This idea of metric equivalents has led more men astray than almost any other. It is absolutely chimerical.

A suggestion which is occasionally heard was put on record by Mr. Christie (page 6, italics mine):

"I would make no immediate change in any of the tools, simply taking them as they are and naming them *to the nearest convenient metric unit.* For instance, call 1 inch 25 millimetres, and so on, with the multiples and subdivisions of the inch." Would he call 3 inches 75 millimetres? Its value "*to the nearest convenient unit*" *is* 76. Would he call it 76? Then, 3 times 1 inch is not 3 inches. Would he call 10 inches 250 millimetres? Its value is 254. This suggestion falls by its own weight.

Another suggestion of Mr. Christie's (page 7) is that "The various pitches of screw thread are entirely arbitrary, and we could distinguish the different pitches from each other by the letters of the alphabet if we chose, or any other nominal distinction that is convenient." I suggest that Mr. Christie draw up such a table of symbols, and then contemplate the task of memorizing it. According to Mr. Christie (page 9) one of the great advantages of the metric system is that it avoids any "undue strain on the memory." Does Mr. Christie think that draftsmen will prefer arbitrary symbols to areas and diameters when figuring strengths?

and not one of which is indicated by any mark on the scales in use, is, however, unthinkable.

When we speak of changing from the English to the metric system, the very thing meant is that we shall abandon sizes shown on the old scales and use those shown on metric scales. This is what has been done by Germany as a nation, and this is what has been done by Willans and Robinson and in the injector department of William Sellers & Co.

Reduced to its lowest terms, there are but two possible alternatives to this question of standards.

1. Retain the present standards with the resulting hodgepodge of part English, part metric measures.

2. Abandon present standards.

56. Many metric converts from the shops accept the first horn of the dilemma, but none of them has shown what is to be gained by a mixed system. The object of this movement is to get rid of our old units in order to do away with "confusion" and make things "plainer." It is incumbent on those who accept the first alternative to explain how these objects are to be obtained by *not* getting rid of them, but by deliberately setting out to keep the old and to add the new to them. That it is *possible* to use such a mixture, as Germany does, counts for nothing. The world is full of examples of what can be done under difficulties. The question is, *How can such a mixed system be an improvement?* With curious inconsistency those who accept this alternative tell us in one breath that the metric system will rid us of the "confusion" of our present units, and in the next they propose to continue the use of the old units for standardized parts. Only a cross-eyed man can see how the mixed use of inches and millimetres can reduce confusion.

Of course Germany uses both inches and millimetres during the transition period just as we will be compelled to do. In Germany *that period has now twenty-eight years to its debit, and the end is not yet in sight.*

57. However the metric neophyte may decide, it is clear that the leaders of this movement have chosen the second alternative, and that, while they put reassuring phrases in the report of the House committee, they do not, as a matter of fact, expect our existing standards to endure. Thus Mr. Shaffroth, in questioning Admiral Melville (pages 118, 119) said (the admiral's answers are omitted):

Do you not think that a truly international system of screws, nuts, bolts, etc., would be desirable? Is not the absence of such a universal system at present due to the fact that England and America have not yet adopted the metric system? Would not the adoption of the metric unit as the basis of the dimensions of screw threads, and the adoption of the American form as the standard, be a fair concession from both sides?

Again, Mr. Stratton testified (page 155):

A change to the metric system of weights and measures would undoubtedly bring about, in time, a change in our system of screw threads, but only at the suggestion and convenience of manufacturers and engineers, as heretofore.

This "convenience of manufacturers" will be reached when the use of a mixed system has become no longer tolerable, for this country will not change its screw threads until compelled to do so. Of all the difficulties of the subject, the greatest centre about screw threads, and our friends show here a distinct disposition to "hedge." Their action, however, is nothing but convenient postponement and evasion, which will not do. They draw pictures of the danger of delay (Mr. Shaffroth, page 44). They point out how much easier the change would have been twenty years ago than now, and how much more difficult it will be twenty years hence than now. If that is true of the general proposition, it is equally true of screw threads. The problem is made no easier by relegating the worst of it to the indefinite future. When we contemplate the adoption of the metric system we must contemplate the *adoption of the metric system,* for the ultimate result is the same, no matter how easy the approach nor how thin the entering wedge.

58. And what is it all for? The metric advocates can answer best. Mr. Christie (page 9) tells us:

I think one of the greatest advantages is its convenience in computation: I think that is unquestionable. The next is, convenience for memorizing; it is a system, which the mind can grasp and readily retain without undue strain on the memory. These, I think, are the two great advantages.

Dr. Wiley (page 50) says:

Now when you see the beautiful relations which exist between the unit of length, weight and capacity . . . . Then there is the direct relation between the unit of length and the unit of weight and we have the measures of capacity that come directly from it.

In answer to the question, What would be the advantage to the general public—the plain people—throughout the country by the adoption of this system? Professor Newcomb answered (page 73, italics mine):

> The advantage would simply be that of simplicity. . . . *So far as every day purposes are concerned I do not know of any particular advantage.* . . .

Dr. Geddings (page 75) says:

> It is simple, elastic, scientific, and on the whole a beautiful structure, and the interrelation and the beautiful correlation which exist between its measures of weight and measures of capacity, and its measures of length and area, I think only require a very limited consideration to appeal to anyone who is desirous of getting into the ranks of the progress of the age.

59. And so on to the end of the wearisome chapter. Was there ever such a case of sacrificing the greater to the lesser? Was there ever such a case of distorted perspective? Was there ever such a case of rainbow chasing? As an epitome of the reasons for making this great change this pamphlet is pitiful. Are we a nation of dreaming idealists and transcendentalists that we should be swayed by such considerations?

The points I have now made are that this supposed universality of the metric system, even in countries in which it has been nominally adopted for a generation, is a fiction; that the idea, which is repeatedly insisted on by these people, that we can make this change in three to five years is rubbish; and that the adoption of the metric system, whatever its advocates may say, does involve the destruction of our existing standards.

The Value of Mechanical Standards.

60. If what has preceded has proven anything whatever, it is that the idea of using metric equivalents for English dimensions must be given up. If this idea must be given up, the inevitable conclusion is that the abandonment of the inch will involve the destruction of our existing standards.

The destruction of our existing standards! A few words, not even a complete sentence. They are easily spoken, but does any one who reads this paper appreciate their appalling meaning, the industrial chaos to which their destruction would consign us? Established industrial standards are among the most priceless of material possessions, and the man who would destroy them deserves to be placed in the pillory and held up to the scorn of men.

The man who can estimate or indicate in words the value of mechanical standards to this country and the loss due to their destruction does not live, and I shall not attempt it. The pamphlet containing the testimony before the House committee is full of questions and of testimony from the metric advocates, the purpose of which is to show that the cost of changing standardized tools is, after all, not very serious, if done gradually, but nowhere is there anything to indicate that these people have any idea of the value of a standard as such. For their benefit, therefore, I will explain that while the value of standardized tools in this country runs into unnumbered millions of dollars, the value of a standard is not chiefly or even largely represented by such tools.

61. The chief value of a standard lies in the fact that it is adopted, that it has become a part of our daily lives, and works so smoothly that we are scarcely aware of its existence. For example, the value of pipe-thread standards is not represented by the taps and dies in the hands of pipe makers and fitters, but by the fact that because the threads are standardized pipe fittings can be made by the million, at trifling cost, and that when we need a fitting we can buy it for a few cents with the assurance that it will fit, instead of having to get it cut to order to suit an odd size of thread. Similarly the cost of attempting to change air-brake hose couplings is not represented by the value of the tools for making the couplings in the Westinghouse Works, but by the infinite confusion of the railroads in getting from one standard to another. The value of the tools in this case is not many dollars, but the cost of the change cannot be found upon any inventory, nor can it be measured by any scale.

Similarly again, the cost of changing our pipe-thread standard is not represented by the cost of new taps and dies, but by the confusion involved in getting from one standard to another—a confusion which will last until existing steam, water, and gas pipes have disappeared, and which will not be lessened by putting off the change until it is brought about "at the suggestion and convenience of manufacturers."

62. It is because of our standards and our standardized methods that American mechanical industries are great. It is in this that we lead, and by this sign we conquer. It is this that distinguishes us from the remainder of the world, and having the

lead which such things give us, we are asked to abandon it and line up in the race afresh. And this in the name of progress.

In this matter of existing standards these people blow hot with one breath and cold with the next. In the report of the House committee they assure us that no change is contemplated, but when driven into a corner they can only suggest that we abandon the old standards and establish new ones, which will be so much better, you know. Thus Mr. Stratton (page 155), quoting from Mr. Sellers, to the effect that the cost of throwing away old taps when the Sellers system of threads was introduced was a judicious expenditure, added:

> Does not this argument apply with still greater force in connection with a universal system of screw threads which this measure does not contemplate, but which is greatly to be desired, and a change to the metric system of weights and measures would undoubtedly bring about in time a change in our system of screw threads, but only at the suggestion and convenience of manufacturers.

In the above, Mr. Sellers describes the discarding of a miscellaneous assortment of taps in order to adopt a standard; Mr. Stratton proposes to discard a standard, which has consumed forty years in becoming such, in order to start a new one. In this he shows that he has so little knowledge of the value of standards, of the time required to get them adopted, and of the confusion involved in changing them, that he takes the inauguration of a standard as a precedent for discarding it.

63. This has been quoted before, but it will stand it again. It is difficult to be patient or to use temperate language regarding such a proposal. Why not throw away our standards and adopt new ones? Why not cut down the trees in Central Park and set out saplings in their places? There is no doubt that, *give him time*, a capable landscape architect could improve the Park. The answer to each question is the same. With trees and standards alike, a generation of time is required for them to take root and grow and become integral with the soil. Moreover, the old standards cannot be cut down. The new must grow up in the shadow of the old, and saplings transplanted to the depth of an old forest are not apt to thrive. Destroy our standards for the sake of new ones that are no better, and that can only become really standard after a generation of confusion. This is the metric programme of simplicity, progress, and reform. And, again, what is it all for? How much compensation will there be in the "beautiful interrelation and correlation of the units"?

Examination of the Claims of Superiority for the Metric System.

64. The keynote of my argument for a time will be that the whole matter is a bagatelle; that, in short, the trifling advantages, if, indeed, there be any advantages at all, to be obtained by the adoption of the metric system are not for a moment to be compared with the enormous cost of making the change. Every thinking man knows that a duodecimal system of numbers would be better than the present decimal system, but no one is so foolish as to seriously propose a change, and the cases are exactly parallel.

On its merits, then, I claim that the metric system is a bagatelle. Admit all, for the sake of argument, that the metric advocates have claimed regarding the fundamental superiority of the system and we admit nothing. The pro-metric argument is that the decimal basis and the interrelation of the units of length, of capacity, and of weight greatly simplify and abbreviate calculations. That is all, for when it comes to actually measuring things no one claims that it cannot be done just as readily by the English system; and, in fact, if there is any argument from this standpoint it is that the English system is better than the French system.

65. In support of this claim of superiority for the purposes of calculation, the standard illustration relates to the calculation of the volume and weight of a tank of water; and, in fact, at the close of the pamphlet giving the testimony before the House committee—a pamphlet which, as a matter of duty, I have read from the first page to the last—are some comparative tables showing the number of figures involved in such calculations by the two systems. Now the weak point of this exhibit is that to very few people is the weight of a tank of water of any consequence whatever. Of the members of this society of engineers I doubt if 10 per cent. ever had to determine the weight of a tank of water or the pressure on its bottom. This illustration is contemptible in its littleness. The calculations of this nature which engineers have to make relate to the weights of masses of the materials of construction—iron, steel, brass, masonry, etc.—and the procedure is the same by either system; we multiply the length by the breadth and the thickness, and then multiply the product by a constant for the material. With the metric system that constant is the specific gravity, and with the English system it is the weight per cubic inch. That is all, and when summed up the

difference in the procedure is simply that between tweedle dee and tweedle dum.

66. Which system involves the more figures in such relations no one can say *a priori* with any certainty. Please note my words. Two factors enter the matter, one of which favors the English, and the other the metric system. The factor which favors the English system is the smallness of the French unit—the millimetre, which is about equal to the one-twenty-fifth part of an inch.

In the practical use of the metric system in machine construction, the millimetre and not the metre, as originally intended, is the unit of length—that is, the figure 1 means 1 millimetre, and not 1 metre. To express 1 metre we write 1,000. The metre, as such, does not appear upon the drawing at all. Eight metres appear as 8,000 millimetres—and what a charming expression that is—it reminds me of nothing so much as measuring the distance to the moon in inches. And this must be so, because we cannot have two decimal points. In the nature of the case, for any class of work, we must first fix the position of the decimal point and then keep it there. Fancy a ledger in which the decimal point sometimes appeared after the dollars and sometimes after the cents. By common consent in metric countries and for machine construction the point is placed after the millimetres.

67. The use of the millimetre as a unit for measuring large dimensions is precisely analogous to the use of the cent for measuring large values, and, just as the expression 7,000 cents, for example, conveys no definite idea of its value to the mind until it is reduced to dollars, so the expression 7,000 millimetres conveys no definite idea of its magnitude until reduced to metres. Dimensions of thousands of millimetres are common on metric drawings.

The smallness of this unit increases the number of figures necessary to express a given dimension, an increase which grows with the dimension. To express a dimension between about 4 and 40 inches we must use not less than three figures, and between about 40 and 400 inches not less than four figures, although in English units these dimensions up to 108 inches can often be expressed by a single figure. Thus the distance which we would call 8 feet is, in the metric system, 2,438 millimetres. This increased number of figures necessary to express a given dimension *increases* the labor of calculation by the metric system.

The effect of this reduction in the size of the unit is startling.

I am not splitting hairs at all. For example, taking the illustration cited above. If I have a surface 8 feet long by 8 feet wide, and I wish to find its area, I multiply 8 by 8, whereas if the same surface has been measured in metric units I must multiply 2,438 by 2,438.

68. To multiply 8 by 8 involves but a single mental act and but four figures—two 8's, a 6, and a 4. Multiply 2,438 by 2,438, and it will be found to involve 32 figures. Moreover, finding the partial products involves the multiplication of four figures by four figures —that is, 16 mental acts. Add the number of such acts required in adding the partial products and in carrying, and a total of 41 distinct mental acts will be found. That is, while the number of figures required to express the dimension has increased fourfold, the number required for the operation has increased eightfold, and the mental labor involved has increased over forty-fold! Of course the case is not representative, and it is not so offered. I do not want any one to imagine that I think the metric system is forty times as cumbersome as our own. I have simply selected an extreme case to show that here is a factor that must be reckoned with,* albeit the pro-metric literature may be searched with a microscope without finding a single reference to it unless the searcher is more lucky than I have been. I doubt if there are a dozen members of this society who ever heard of it before, or

* It is not necessary to jump from millimetres to feet nor to confine ourselves to integral English dimensions to illustrate this small unit effect. In place of the surface assumed in the text assume one of 8½ inches or 216 millimetres (decimals omitted) square, and the operations of finding the area are as follows:

English	Metric
8½	216
8½	216
—	—
4¼	1296
4	216
64	432
—	—
72¼	46656

Summing this up we have the following results:

	English.	Metric.
Number of figures required to express the dimensions................	3	3
Number of figures required to work the problem....................	16	21
Number of mental acts	6	17

Like the other, this illustration is not offered as a representative problem, but *to demonstrate the action of the small unit.*

one who ever before saw it reduced to figures. That this small unit effect acts to largely reduce the savings due to the absence of fractions is as clear as the sun at noon.

69. That more figures are required to express a given distance in a small unit than in a large one is certainly obvious, that this, taken by itself, tends to increase the labor of calculation is also obvious, and that the mental effort increases far more rapidly than this increase in figures is shown by the illustrations. That this effect must be placed against the gain due to the absence of fractions in order to obtain the net effect, is as clear as anything on earth can be. Nevertheless this effect is completely and conveniently ignored by the metric advocates.

When it comes to the claim that this metric system reduces the labor involved in the calculations of every-day life enough to be *a matter of any public moment whatever*, it simply is not so.

This action is always present—albeit often offset by the absence of fractions—whenever we deal with quantities larger than 1 centimetre.

No dimension on a machine drawing above 9 millimetres (about $\frac{3}{8}$ inch) is ever expressed by a single digit, and none above 9 centimetres (about $3\frac{1}{2}$ inches) by two digits. In English units 9 feet may be expressed with one figure, and 99 feet with two. Talk about simplicity. A metric drawing is a wilderness of figures.

70. Even the assumed simplicity of decimal fractions is to a large degree fictitious. Compare the following table of equivalents:

$\frac{1}{3} = .3333 +$	$\frac{1}{60} = .0166 +$	$\frac{1}{16} = .0625$
$\frac{1}{4} = .25$	$\frac{1}{70} = .0143 +$	$\frac{1}{32} = .03125$
$\frac{1}{5} = .2$	$\frac{1}{80} = .0125$	$\frac{1}{64} = .015625$
$\frac{1}{6} = .1666 +$	$\frac{1}{90} = .0111 +$	$\frac{1}{360} = .0028 +$
$\frac{1}{7} = .1428 +$	$\frac{1}{200} = .005$	$\frac{1}{450} = .0022 +$
$\frac{1}{8} = .125$	$\frac{1}{300} = .0033 +$	$\frac{1}{540} = .0018 +$
$\frac{1}{9} = .1111 +$		

Read some of these expressions aloud. One-eighth equals one hundred twenty-five thousandths; one sixtieth equals one hundred sixty-seven ten thousandths; one thirty-second equals three thousand one hundred twenty-five hundred thousandths. Can any one say that the decimal equivalents give as clear a mental picture of their value as the vulgar fractions? They never do, except where the decimal is small, and this explains why people insist on using vulgar fractions.

The superiority of the decimal system as applied to currency is largely due to the great amount of adding to be done. With day book, journal, ledger, cash book, trial balance, balance sheet, invoice inward and invoice outward alike, it is add, add, add, and then add some more. The amount of adding to be done in connection with money is both relatively and absolutely out of all comparison with that involved in connection with weights and measures. When it comes to multiplication or division, vulgar fractions are often the simpler. The comparisons drawn between currency and weights and measures will not bear examination.

71. Some very striking testimony on the subject of the comparative labor of calculations by the two systems was offered before the House committee by Mr. J. H. Linnard, a naval architect of the Navy Department, who learned his profession in France, where he spent four years studying naval architecture in the metric system, which profession he has practised since 1887 in this country, where, of course, he has used the English system. Here is a man who may fairly be said to know what he is talking about, and, moreover, one would expect his predilections to favor the metric system, as, in his schooldays, naval architecture and the metric system were part and parcel of the same thing. Nevertheless he testified (page 183): "As far as calculations in the matter of shipbuilding are concerned, it is just as convenient in every way, shape, and form to use English measurements as French."

Such testimony cannot be ignored. It is worth more than all the essays and *a priori* arguments that can be written from now until doomsday. There is probably no branch of engineering which involves so many or such laborious calculations as ship designing. It may be regarded as the crux of the whole matter. Moreover, in connection with many of the problems of the naval architect the pet tank of water illustrations would seem to apply directly, but, unfortunately, the naval architect has to deal with salt water, which has a greater specific gravity than fresh water, and so these pretty illustrations fail to apply even here. If the Creator would kindly make the earth over again and fill the seas with distilled water the case might be different.

72. The following testimony from another article by Mr. Hess, published in the *American Machinist* for October 16, 1902, is even more striking, because Mr. Hess, before his practical experience with the metric system, was an advocate of it:

Some years since I was asked to sign a petition to Congress asking that the metric system of measurements be officially adopted as the legal American standard. In common with many others I complied, under the impression that the ease of reckoning with decimals and the convenience of a logically harmonious system would be sufficient to compensate for all troubles, fancied and real, incidental to the change. Since then actual experience with the metric system has led to a revision of views, so that to-day I am decidedly "on the fence."

That the metric system is a really satisfactory solution of the problem is, to say the least, doubtful. The convenience of its units as to size is debatable; but it is very likely that no series of units can be generally satisfactory. The requirements of the various arts and sciences are far too varied for that. The best unit, or series of units, is one that does not involve large figures.

That argument of the advocate of the metric system that its unit, the metre, is a natural one, a certain definite portion of the earth's diameter [*sic*], may be at once dismissed; it has already been proven that the metre's relation to the earth's diameter is, or was, not reliably known.

There remains the other chief claim—convenience in reckoning, owing to the metric system having been built up on the decimal plan. This is really a very alluring claim, but will not bear close scrutiny. The decimal system is only in part more convenient than a binary system, but not wholly so, or even more so. It is in fact more uncertain in arithmetical operations than the decidedly faulty English system. This statement, directly opposed to my preconceived notions of a few years ago, is advanced as a result of direct experience with the metric system, extending now over three years. Having been gradually led to this conclusion I determined to put it to a practical test. A certain problem—not made up specially for the occasion, but cropping up in regular practice —was submitted to seven draughtsmen and designers, some of them of more than average attainments, and all of them thoroughly familiar with the metric system, through having used it almost exclusively in their practice and schooling. The correct result was arrived at by only three of the seven men.

The problem was at first given to but one man, and only the obviously wrong result led to its being handed over to the others. The difficulty lay in the correct location of the decimal point; with one exception all had the correct numerals, but the men were apparently lost in the maze of decimal figures.

The same problem with equivalent values in English units was then handed out. The correct result was arrived at by six out of seven men in an average of two-thirds the time taken for its solution in the metric system, showing that the percentage of error was very much less and the time considerably less with the binary system, notwithstanding the relative unfamiliarity of the men with the units of the binary system.

A decimal system is not as convenient as a binary system in mathematical, draughting-room or shop work at least so far as mechanical engineering is concerned.

Additional evidence unfavorable to the claims for economy of time in calculations will be found in the reply to Mr. Christie's contribution to the discussion.

73. But ignore Mr. Linnard's and Mr. Hess's testimony if you will, and what does the pro-metric argument amount to? Suppose

the labors of naval architects and engineers generally were appreciably lightened by the use of the metric system, what would it amount to? What is the proportion of engineers to the public at large, and how much would the aggregate saving amount to? Figure up the aggregate if it can be done, and then divide it by the number of the population, and how many seconds per day for each man would be obtained? This explains what I meant in saying that if the arguments of the metric advocates be admitted the admission amounts to nothing. As an economic factor in the life of this people, I insist that the saving of time due to the use of the metric system in calculation is an absolute bagatelle. No microscope ever magnified material things to the extent that the importance of this matter has been magnified. I cannot express my contempt for the argument that, in order to lessen the labor of a man here and there throughout the country, this nation should be put to the confusion and turmoil involved in tearing up by the roots the most fundamental feature of its commercial and industrial life. The proposition is unthinkable. Talk about special legislation; the words do not describe it.. The only field in which the interrelation of the units cuts any considerable figure is the electrical field. This narrows the issue still more. Shall we do this for the electrical engineers?

74. Again, *what is it all for?* Such a change as this is justifiable only in case of great and manifest advantages. Why, then, should we embark on this movement, the end of which no man can foresee, when its advantages, granting them to exist, are so slight and so elusive that—with unexcelled opportunities for comparison and formerly an advocate of the system—a man like Mr. Hess cannot find them?

In this connection I wish to call attention to another matter. Engineers are no longer subject to the drudgery of calculations. For the past twenty years an instrument for this purpose has been growing in use, until it has become almost universal among engineers below middle life, its use being taught as a matter of course in our engineering colleges. I refer to the slide rule, which has become almost as familiar a thing on an engineer's desk as well as on those of many commercial men, as a lead-pencil or a pair of dividers. It performs all the ordinary calculations of life, except addition and subtraction, so quickly that there is nothing left for the metric system to save, and as an economic factor in the life of the American people it is worth twenty metric systems. These people consider us a lot of mossbacks and old fogies. As a matter of fact, it is they who are twenty years behind the times, for they do not know that the drudgery of calculations is already a thing of the past.

75. To go back to the calculation of constructive weights, no one to-day would do it except by the slide rule. For this the small numbers due to the large units of the English system are distinctly superior to the large numbers due to the small French units. With the former we determine the decimal point instinctively, while with the latter we must keep tab on the decimal point.

Putting the little slide rule alongside the great *systeme universelle* may appear to some like standing Jack the Giant Killer alongside his victims, but do not forget the final result.

Moreover, the entire argument for this saving of time in calculation is based on the tacit assumption that the old units will become extinct since, if they are to be used, they must appear in calculations. When, as in French and German textile industries, the old and new units are used conjointly, there is an actual loss of many times the theoretical gain.

Witness the closing of the grave over a century of delusion regarding a wonderful saving of time in calculations, to be obtained by the adoption of the metric system.

The Foreign Trade Argument.

76. As a matter of public policy the only view of this question which is of any moment, is that which asserts that the adoption of the metric system is necessary in the interests of foreign trade. If this view were true as a general proposition—which I shall show it is not—it would still be no sufficient reason for governmental action. There are a few parts of one line of machines which it is important to have made in accordance with the system of measurements employed by the user. In making such machines for countries using the metric system, our manufacturers have adapted themselves to this fact, and if they are half as astute as we all believe them to be, they may be depended upon to so continue. A manufacturer is certainly in far closer touch with his customers than any government can be, and this subject, which is so interwoven with all business interests, is the last one in which what has been called "the clumsy hand of legislation" should interfere.

77. In the appendix I have shown how and why the machine-

building industry is the foundation industry of modern life, and carrying the simile still further, the machine tool-building industry is the footing course of the foundation. It is by these machines that all machines—including themselves—are made. In this distinction they stand apart from all other products of human skill, and when one is in a machine tool-building shop, he may be very sure that he is witnessing the primal industry of our time. This is the absolute zero of modern industry.

The man who buys machines of this class does so in order to make other machines. By them all parts of all machines are made to the required size.

If this assertion that export trade requires the adoption of the metric system were true at all, it would, for this reason, be doubly true in connection with machine tools. What, however, are the facts? Of all the developments of our export trade in the last half-dozen years, none has been more pronounced than in this class of machines. In number and variety those sent abroad have been legion, and of all countries of the world Germany has been our best customer, with France not far in the rear. I have made it my business to inquire how many and what changes machine tool-builders have found called for by their foreign customers, and the answer settles this contention. I have said in the appendix that one of the Cincinnati milling machines contains 18,300 dimensions; of these that company has found occasion to make two to metric dimensions, these being the pitches of the traversing and elevating screws of the milling machine table. These two screws are distinctly measuring screws, and the need of their being made to metric pitches is obvious to any mechanic. The lead screw of lathes is a similar measuring screw, and this likewise in many—though by no means all cases—must, when sent to metric-system countries, be made to metric pitch. *These three screws comprise all the parts of the hundreds of parts of the thousands of machine tools sent abroad that have needed change,** while in steam engines, mining, agricultural, and other lines of machinery no changes whatever have been called for.

* This should be understood as meaning that these are all of the changes that I have been able to find. No doubt there are, here and there, in machine tools, adjusting screws analogous to those named which have needed changing, but the essential fact is that the changes have been absolutely infinitesimal, and that, so far as general construction is concerned, no changes whatever have been needed.

78. That there may be no possible doubt about the facts being as stated, I refer to the action of the Cleveland (October, 1902) Convention of the National Machine Tool Builders' Association, which condemned the bill now before Congress, among other reasons

> Because the sale of many million dollars' worth of machine tools has been made abroad by members of this association, especially to France and Germany, without requirement or request by the purchasers for changes in general construction to conform to metric measurements, the only changes being in adjusting and measuring screws, the great majority of machines needing no changes whatever."

Further confirmation of these facts is found in the letter by M. Benét, of Hotchkiss & Cie, Paris, of which portions have already been given. He says:

> Practically the question has no personal interest for me, as we of course work in our own shops to the metric system, and this has in no way prevented us from doing a large business with the Governments of the United States, England, Russia, and other countries. We are using a very large amount of American machinery in our works, and the fact that this was all built to English measures has given no difficulty. Of course the leading and cross feed screws are supplied to metric pitch, but, as you say, this involves two dimensions out of the many thousands that enter into the drawings of a machine. All of the newer and most up-to-date establishments in France, including all of the Government establishments, are largely equipped with American machinery, and I know of no case where the fact of the machines being built to English measures affected their sale ability.
>
> I believe that the passage of the proposed bill will be the cause of much loss of accumulated wealth, of much confusion, and that the adoption of the metric system will in no way affect the trade of the United States for the better.

I have one fact to add which is still more striking. The Chandler & Taylor Company, of Indianapolis, build saw-mills, which they export largely, having specially large markets in Central and South America—metric using countries, according to our friends of the other side—and for whom Chandler & Taylor have issued a Spanish catalogue. A saw-mill has a feed works composed of levers, gears, etc., by which the log is fed forward after each cut, and by this gear the thickness of the boards is determined, this feed gear being regularly made to cut the boards to English dimensions Six years ago the Chandler & Taylor Company inserted in their Spanish catalogue a statement that, on request and without extra charge, they would make this gear to cut the boards to metric dimensions, but, unless otherwise specified, they would furnish the English gear, and up to last April not one inquiry or request for the metric gear had come in.

79. The statement that goods must be made to metric dimensions in order to sell in metric countries is as broad as it is long It simply asserts that in order to sell, goods must be made in accordance with the system of measurements used by the purchaser, and from it it follows that in order to sell here, goods must be made in accordance with the English system. What, however, are the facts? For forty years the Sellers' injector has been made to metric dimensions (excepting always the screw threads), and no one was ever heard to object to it on that account. There are a dozen other American makers of injectors, all of whom, I believe, use the English system, and no one can say that at least some of them do not make good injectors. A purchaser who objects to the metric dimensions of the Sellers instrument can certainly satisfy his wants elsewhere, but I am not aware that any one has ever been heard to raise the objection.

We may, however, take a broader view of the matter. From the *Monthly Summary of Commerce and Finance*, published by the Treasury Department, I learn that during the year ending June 30th last there were imported into this country $480,000,-000 worth of manufactured and semi-manufactured goods, which sum does not include $265,000,000 worth of "articles of voluntary use, luxuries," etc., *some* of which were probably manufactured.

80. According to our metric friends all of these goods, except those from England and her colonies, are from metric countries, and perforce must be made in accordance with the metric system. I am unable to determine the percentage of metric goods from the tables given, but did any one ever hear of a single instance in which such goods were objected to because they were not made in accordance with the English system?

In buying a machine, for example, the customer needs to know certain facts, and these facts should be given him in language he can understand. Among such facts are the weight, the length, width, height, and the capacity. If the machine is a planer, for example, the customer must be told the largest size of work which it will do, as well as its weight and over all dimensions, in his own language, which includes his system of weights and measurements. To give such facts in the metric system no more involves the adoption of the system than the furnishing of a catalogue in the German language involves the adoption of that language. That the foreign customer should care whether the working parts—the shafts, the gears, the levers, etc.—are made to metric dimensions or not is ridiculous. Machines are sold by their operating qualities, the price, and the time of delivery, and not by the fact that a certain shaft is 25 millimetres in diameter instead of 1 inch.

81. Just as the idea of using metric equivalents for existing dimensions has misled many mechanics, so this need of the foreign purchaser for such information in units with which he is familiar has misled many commercial men. They imagine that because a foreign buyer needs such leading weights and measurements as would be given in a specification or in a letter describing the article offered for sale in metric units, that therefore it is necessary to adopt the metric system in factory operations. The use of metric units in this descriptive or specification way when writing to a prospective German customer, for example, is exactly analogous to use of the German language under the same circumstances. Both serve to put the information which the customer wants in terms which he can readily understand.

At his notable inaugural address as rector of St. Andrew's University, Scotland, Mr. Andrew Carnegie urged upon the nations of Europe the necessity of an alliance against this country, and told them bluntly that unless they agreed to something of this kind, all they could look forward to was to

> Revolve like so many Lilliputians around this giant Gulliver, the American Union.
>
> Can Europe, as long as she remains divided into hostile camps, ever hope to conquer foreign markets or even to repel the American invasion? Never.
>
> America now makes more steel than all the rest of the world. In iron and coal her production is greatest, and it is also so in textiles. She produces three-quarters of the world's cotton. The value of her manufactures is about triple that of your own. Her exports are greater, and the clearing-house exchanges at New York are almost double those of London.

If the metric system is necessary in the interests of foreign trade, as the metric advocates assert, why has the "American invasion" made such progress in the continent of Europe? Why have our exports of manufactured goods increased during the past half-dozen years at a rate which is unexampled in the history of the world?

Analysis of the Bill.

82. Following is the text of the bill as reported to the House of Representatives by the Committee on Coinage, Weights and Measures.*

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That on and after the first day of January, nineteen hundred and four, all the Departments of the Government of the United States, in the transaction of all business requiring the use of weight and measurement, except in completing the survey of public lands, shall employ and use only the weights and measures of the metric system; and on and after the first day of January, nineteen hundred and seven, the weights and measures of the metric system shall be the legal standard weights and measures of and in the United States.

The Attorney-General has given it as his opinion that the terms of the bill do not make the use of the system compulsory in general business transactions, and the thoughtless may, therefore, conclude that there is no cause for alarm.

No one can read the pamphlet to which I have referred so often without seeing behind this whole movement the spirit of compulsion.

83. Thus after Mr. Christie had deprecated compulsion, Mr. Shaffroth said (page 8): "I will state that it is about the only way it has been introduced. Germany adopted it by compulsory statute of the Reichstag, and I do not see how you can do it any other way." (And he was quite right.) Again Dr. Stratton (page 153) was asked by Mr. Gaines: "You would make the law compulsory?" to which he replied (italics mine): "*That would depend upon the time allowed for its adoption.*"

Here is this great mass of testimony, of which the overwhelming apparent preponderance is to the effect that the people want this system. So far as producing any real adoption of the system, the bill will, of course, prove absolutely abortive. What then? What more natural than that this thing, which by the record the people want, shall be made compulsory after gentler means have failed to accomplish what the people desire? This has been the history of metric legislation everywhere. The difficulty of the change has been ridiculously underestimated, and law after

* The text as given is from the *Journal of the Western Society of Engineers* for August, 1902.

law has been passed to make previous laws effective.* The inclusion of English yarn counts in the German tariff schedule, of which particulars have been given, represents the defeat of an attempt to make previous laws effective by compelling the exclusive use of the metric system in German textile industries. The interests adversely affected made such an outcry as to defeat the bill as originally drawn.

84. The article by M. Lamoitier, from which extracts have been given in the section relating to the persistence of old units in France, closes with a strong appeal for another law to compel the use of the system in French textile industries. And this in France after a century of the metric system! He has, it may be added, the same cheerful confidence in the sufficiency of one more law to accomplish the purpose that our metric advocates have in the sufficiency of the bill now before Congress to bring about this great change among us in from three to five years.

The fact that, as regards those who do business with the government, the bill is already a compulsory measure is enlarged upon in the reply of Mr. Southard's contribution to the discussion.

The scientific method has demonstrated beyond the possibility of a doubt that changing a people's system of weights and measures is a matter of mountainous difficulty and of endless confusion. It is time that the American people and the American Congress learned this fact. If we keep silent now our voice can have little weight later. Now is the time to speak if we are to speak with any effect.

It is not easy for a layman to determine the meaning of the term legal standard. Judging by the words of those who ought to know (for example, Mr. Shaffroth, page 119), the phrase means that after January 1, 1907, the metric system is to be used in all actions-at-law into which weights and measures enter.

85. As I have said, the effect of the bill, so far as any real adoption of the system is concerned, is certain to be abortive, and its real effect, so far as the general public is concerned, will be to compel the use in actions-at-law of a system of weights and measures with which neither witnesses, jurymen, lawyers, nor judges will be familiar.

As regards the adoption of the system in the Government business, it is uncertain what is meant by it, except that the metric

* See Mr. Colles's paper, vol. xviii., p. 492, of the *Transactions*.

advocates are determined that all Government purchases shall bear the metric label. If this provision of the bill means that Government purchases of machinery are to be made in good faith to the metric system, as that term is understood in France and Germany, then in many lines the Government will go without machinery altogether, and it will pay exorbitant prices in others. If, under the stress of these circumstances, enforcement of the law is relaxed, and we do with the Government as we now do with foreign customers—give the weight, over all dimensions, swing and extreme length of work a lathe will take in, for example—and call that the *adoption of the metric system*, then the Government will be the manager and the Government officials the actors in the greatest farce-comedy of recent years.

86. That the metric system can become our real factory system of production within any reasonable time the experience of other countries abundantly proves to be impossible, and the requirement that the system be used in all Government work can do nothing more than to force the adoption of a special system for that work; in other words, and in the name of simplification, compel the use of two systems where we now have one.

In conclusion, the skies are black enough, but there is nevertheless one bright, particular star which no cloud can hide—this metric programme is hopelessly impossible. Germany is held up to us as our great exemplar, but the example counts for nothing. When the German Empire was formed the various States had each its own units, which still survive, as has been pointed out. The necessity of getting rid of such a condition of things was obvious. State jealousy made the adoption of the system of any one State impossible, and, as the only way out, the country turned to the metre. *Germany adopted the metre in order to do away with confusion; our adoption of it will only make confusion.**

The facts are thus expressed by M. de L'Espée, who has already

* The same condition of a multiplicity of units varying with every district and even town, was what led to the original invention of the system in France, as Mr. Ball's letter, paragraph 34, has shown the same to be true of Spain. Throughout the length and breadth of the United States and of the British Empire, there is not and never has been any comparable condition. The reason which has led to the change elsewhere is here lacking; the uniformity which it was elsewhere hoped it might secure, it will here destroy. The reasons which have led other nations to adopt it are exactly the reasons which should lead the Anglo-Saxon nations to have nothing to do with it.

[illegible] prevailing in France and Brazil.

* The chief advantage of the [illegible] system [illegible] the substitution of a uniform, unchanging standard for the endless confusion of standards that prevailed in France and in other countries prior to its adoption, is well known to have been the main cause of its [illegible].

[illegible]

[illegible] compared with ours. Comparison between the development of German industries thirty years ago and our own day there is none, and every [illegible] industry, every mill, every machine, every material thing we have, is another being made to the inch. These people may legislate till doomsday, they may make infinite confusion, endless turmoil, limitless sacrifice, but move the English inch?—the Archimedian lever is still unknown.

APPENDIX.

Of the Fundamental Importance of the Measuring Industry in Modern Life and of the Importance of Certain Testimony.

44. This argument is a growth of twenty years. When a student I had the great good fortune to do a little work on the first standard measuring machine made in this country. In connection with that I obtained a little insight into what this subject of measurements means, and the profound interest thus excited has continued. The subject and its ramifications are boundless. This paper is but a pin-scratch upon its surface. Weights and measures are the warp and woof of our industrial life. To change them without destroying the fabric which they compose is hopeless.

Next to language, weights and measures are the most fundamental of our possessions. All knowledge is comparative, and comparison is impossible, except through the use of weights and measures. Take away our measures of length, of weight, of capacity, of value, and of time, and no life beyond that of the most primitive savage is possible. With this fundamental nature goes a corresponding difficulty of change—a difficulty which, there is abundant proof, is only equalled by the difficulty of changing language itself. Practically both are upon a par, for I believe it to be just as impossible for this people to change its weights and measures as to change its language. No nation in modern times has ever gotten rid of an old system, as my argument has shown for the cases of France and Germany.

89. As my argument relates chiefly to measures of length as used in machine construction, it is important to explain the different bases upon which measures of length and other measures stand. The simplicity, universality, and cheapness of commercial measures of capacity and of weight are obvious to all. The gallon measure and the counter and platform scales of the grocer cost but little, while they weigh and measure all his commodities, except those sold by count. Contrasted with this, commercial measures of length as used in the machine shop are numbered by the hundred and by the thousand, and are of a far higher degree of precision than measures of weight and of capacity. There is no reason why every gallon of molasses should be the same—to the last drop—as every other gallon, and there is no reason why the weight of a barrel of flour should agree, to the last fraction of a scruple, with every other barrel. Precision in these things is merely a commercial matter, and the commodities have not enough value to justify the cost of minute accuracy in measuring them.

90. In the case of measures of length in the machine shop a new element enters. We do not make a given piece of a machine to a precise size, because we fear the customer will get more iron or steel than he pays for, or for fear he will complain if we do not give him all he pays for. We make it to precise size in order that all similar pieces may be alike. The feature of interchangeability, which is a necessity of economical manufacture, compels these measures to be made with a degree of precision to which there is no parallel in commerce elsewhere. A thousandth of an inch of error represents a very common degree of accuracy, and

no work which does not come within a quarter of a thousandth can be called precise. A tenth of a thousandth is sometimes seen, while standard gauges are guaranteed to be correct within a fiftieth of a thousandth of an inch.

It is thus clear that, commercially speaking, measures of length are in a class by themselves, for not only is such precision unknown elsewhere in commerce, but such results involve a degree of refinement and cost in measuring instruments which also are unknown elsewhere. Moreover, unlike the scales and measures of capacity, instruments for measuring length are not so nearly universal, but must be made in variety and in numbers of which the public-at-large has no conception.

91. This phase of the subject has, however, a far wider application than to the machine shop. This is the mechanical age. Without machinery is nothing made that is made. The machine building industry is the foundation industry of modern life. Were Tubal Cain to return to earth to-day, he would be a machinist, and not a blacksmith. The textile arts, the lumber industry, pottery and glassware making, mining, metallurgy, the making of our books and papers, and even agriculture, are to-day carried on by the aid of products of the machine shop. The same is true of transportation. The railroad is but the child of that magnificent machine, the locomotive. It could not be built without the contractor's plant of machinery, nor could its rails be made but for the rolling-mill, which was made in a machine shop. The steamship, whether commercial or naval, is but an aggregation of machinery and mechanical products, while the implements of war have been revolutionized again and again by the machine shop. Our homes and their furnishings, our clothing, our fuel, the very food we eat, tell the same story, while the water we drink, and the gas or electricity which turns night into day, come to us through the water works, the gas works, and the electric generating station. About the only necessity or luxury of life which does not come to us through the aid of machinery is the air we breathe. That is the one raw material of nature which does not need the magic touch of machinery to fit it for the use of man.

92. The meaning of all this, and the point to which I am leading up, are very simple and very plain—namely, that to cripple the machine shop is to cripple every other industry under the sun, and to defend the machine shop, directly, is to defend, indi-

rectly, every industry by which the American people thrive, and prosper, and earn their daily bread. It is to defend even those industries whose representatives go to Washington and declare that they want this thing; for I want to say that when these men go there, and in their mistaken zeal seek to crucify the English system of weights and measures, they simply know not what they do.

There are many industries in which measurements play a subordinate part. We may buy a shipload of grain by specifying the number of bushels, or of pig-iron, or of coal, by naming the number of tons. But when we buy a machine we buy measurements by the hundred. The Cincinnati Milling Machine Company inform me that one of their medium-sized milling machines, selling for $650, contains, including the pattern work, 18,300 dimensions—that is, a little over 28 dimensions for each dollar of value. Of these, the majority probably require to be correct to the thousandth of an inch, and many of them to a much higher degree of precision than that. I think this illustration will make it plain why this matter is of such momentous importance to the machine building industry, and why this society should be united in this matter.

In this connection I quote the following paragraph from a speech by Senator Platt of Connecticut:

> All history confirms us in the conclusion that it is the development, by the mechanic arts, of the industries of a country which brings to it greatness and power and glory. No purely agricultural, pastoral people ever achieved any high standing among the nations of the earth. It is only when the brain evolves and the cunning hand fashions labor-saving machines that a nation begins to throb with new energy and life and expands with a new growth.

Of the Incompetence of Certain Testimony.

93. Much of the testimony offered at Washington has no significance whatever. The mere "It's a good thing, push it along," of some commercial man, even of the most exalted station, should have no weight, for he can have no knowledge of constructive measurements. Nor should the testimony of scientific enthusiasts, who are captivated by the nicety of the thing. *This is in no sense an academic question.* The industrial use of measurements is in the

making of things, and hence this is a factory question, and not a laboratory or a study question at all. There is, however, one class of testimony which deserves fuller notice —that of many engineers and engineering societies who endorse this bill. It may well be asked why the views of these engineers are not entitled to as much respect as our own. These men are chiefly civil engineers, and their societies are chiefly civil engineering societies. Except for the Franklin Institute—whose mechanical section is but one of many—no mechanical engineering society has, I believe, endorsed this measure. It may still be asked why civil engineers are not entitled to their views as well as we. *They are, regarding their own units, but not regarding ours.* Civil engineers deal with constructive measurements, but a characteristic of their work is that each piece of it, be it bridge, canal, or dam, is complete in itself, designed and built for its place and work, and in its measurements has little to connect it with the past or future. There are, however, two classes of measurements which are especially within the province of the civil engineer—land and angular measurements, of which the former are expressly exempted from the operation of this bill. Angular measurements are also within the special provisions of the American and Canadian astronomers, the superintendent of the coast survey, and the American astronomical instrument maker, who testified before the House committee in favor of the bill. These gentlemen are distinguished men. No one honors their achievements more highly than I, but that does not change the facts about their testimony.

94. Our angular measurements are as illogical as any. It is just as illogical to divide the quadrant into 90 degrees, and each degree into 60 minutes, as to divide the pound into 16 ounces, or the foot into 12 inches. An integral part of the metric system in its entirety is a new system of angular measurements, in which the quadrant is divided into 100 degrees, and each degree into 100 minutes.

95. We hear no call from civil engineers for a new set of units of land measure. Why? Because in land measure it is too plain to be overlooked that "measures of length are tied irrevocably to the past"; hence civil engineers will not have such measures changed. We hear no call from civil engineering or astronomical circles for a new system of angular units. Why? Because, were the change made, not an old observation or record could

be read in the new units, nor a new observation in the old units.* Measures of angles, like those of length, are "tied irrevocably to the past," and hence these men will not even consider a change in angular units. Their motives are not to be impugned; they see their own side of the shield, and do not see ours; but, nevertheless, until these gentlemen are prepared to accept a change in their own special units, *they are estopped from urging a change in ours.* What a spectacle for gods and men is a civil engineer, urging a new set of units which do not include those for land and angular measurements !

96. How much knowledge does the average commercial or scientific man have of such questions as the value of a screw-thread standard, or the difficulty of changing such a standard? If he has no knowledge of such things, his opinion on this subject has no value.

This brushing aside of the testimony of commercial men, of scientific men, and of civil engineers, may appear somewhat summary, but I believe the logic with which it is done to be without a flaw.

It cannot be too much emphasized, that to learn anything of moment about industrial measurements one must go to places where such measurements are made, chief of which is the machine shop.

Moreover, as I have tried to show, this programme involves heavy cost and sacrifice to manufacturing interests. What right have those who have no pecuniary interests, I state, to force this thing upon others who must pay the cost ?

I can imagine no more appropriate close for this paper than another reference to Mr. Stratton's testimony. Said he (page 153):

> Let us take for example the most serious objection of all, which is that we have learned to think in the old system of weights and measures.

Does Mr. Stratton seriously consider that the persistence of the ells in Continental Europe, and of the *vara* in South America,

---

* The words of the text apply without the change of a syllable to every record, observation and datum recorded in English engineering literature. Of the vast mass of recorded experimental and working data on which the practice of engineering rests there is not an item that can be read in metres and kilogrammes, nor of new observations in metres and kilogrammes will there be an item that can be compared with the old, except after translation.

can be explained at this late day by saying that the people "have learned to think in the old system"? Can he see nothing but this in the use of the carat for weighing jewels by people who, presumably, use the gram for everything else? Is it not plain to him by this time that the objection which to him appears to be the "most serious of all," is, in reality, dwarfed by the fact that "measures of length are tied irrevocably to the past?"

DISCUSSION.*

Extracts from Letters.

From Charles E. Adams, President, Massachusetts State Board of Trade, Lowell, Mass.:

"I have read Mr. Halsey's very able and interesting paper, and appreciate many of the difficulties suggested in making such a radical change where so many interests are using, and must continue to use for some time, the weights and measures in custom throughout the United States and Great Britain.

"A careful reader of consular news from all parts of the world to the American and English governments, cannot fail to be impressed with the fact that both

---

* The paper of Mr. Halsey was distributed in advance of the meeting to a large number of persons not members of the Society, who, by reason of their position or experience, were felt to be in a situation to present considerations of weight in its discussion. Among these were persons interested in the manufacture of machine tools as builders or exporters, or both. The volume of these letters was so great that the Publication Committee have not felt justified in publishing them in their entirety, even when contributed by members of the Society. The originals are on file at the rooms of the Society for any who may be interested in consulting them as sources of information at first hand. A sample of such letters is given below, and a list appended of others which were of practically the same tenor. Brief extracts from other letters are put at the head of the discussion as contributed in writing and orally, in the ordinary forms of such contributed matter.

A paper prepared by Mr. Edward P. Bates, with great care, has also been omitted from the discussion which treated in considerable fulness of the connection between the standard units of the English system and an existing natural origin for such units. The paper was carefully digested to present in compact form the argument advanced in "A Miracle in Stone" by Joseph A. Seiss, D.D. 14th Edition, Philadelphia, Pa., pages 58 to 65 and 245 to 247. Those interested in pursuing this branch of the subject further are referred to the original sources.

The sample letter from builders and exporters of machine tools is as follows:

"Less than one per cent. of our total sales in France and Germany call for metric lead-screws, and no other parts are required to conform to the metric measurements.

"It is very difficult for us to estimate the cost of machinery to the Government, should they demand that it be made according to the metric system. It would, nations are suffering a great loss financially by ignoring the metric system when placing manufactured products in foreign markets.

"The practical business man recognizes the many obstacles to overcome, not

---

however, be impracticable for us to supply machines built to these specifications and at the same time produce a general line of goods built on the English basis.

"The cost of changing from the English standard to the metric system, throughout our shop, would undoubtedly involve a loss in excess of our profits for a number of years to come. We have, by putting forth every effort, succeeded in introducing in all departments of our works full sets of standard gauges. Our drawings, tools, fixtures, etc., are all based on the English units. We consider that it would be a very serious detriment to our business to be obliged to change; and would anticipate great difficulty in educating our workmen to the new standard. Signed,

"E. P. BULLARD,
"President Bullard Machine Tool Company."

Letters were received from other members as follows:

Lewis Searing of the Denver Engineering Works,
Fred L. Eberhardt of Gould & Eberhardt,
Walter Laidlaw of the Laidlaw-Dunn-Gordon Company,
Harry M. Lane of the Lane & Bodley Company,
William Lodge of the Lodge & Shipley Machine Tool Company,
Fred A. Geier of Cincinnati Milling Machine Company,
Samuel L. Moyer of the Lunkenheimer Company.

Letters of similar purport were also received from the following firms:

American Tool Works Company,
Baldwin Locomotive Works,
Cincinnati Machine Tool Company,
Cincinnati Shaper Company,
I. & E. Greenwald Company.
Cincinnati Planer Company,
Deats Machine Tool Company,
Northern Engineering Works,
Greaves Klusman & Co.,
Cincinnati Punch & Shear Company,
Bradford Machine Tool Company.
Fosdick Machine Tool Company,
J. H. Day Company,
Aurora Tool Works,
Sabastian Lathe Company,
Schumacher & Boye,
Belmar Machine Tool Company,
John Steptoe Company.

Letters were received in endorsement of the metric system from the following:

Godfrey L. Cabot, Boston, Mass.
E. W. Lyttle of the College Department University State of New York.
Rufus P. Williams, Pres. New England Association of Chemistry Teachers.
Elihu Thomson of the General Electric Company.

only in mechanical engineering and industrial instruction, yet it is believed that sufficient time will elapse between the enactment and enforcement of the proposed law to prevent any hardship to the people.

"The reform seems radical, but I believe that the adaptability of our American manufacturers to new methods however difficult, if deemed profitable, will be met and result in largely increasing our trade in foreign markets, now held by industrial nations who use the metric system." *

From Eugene W. Lyttle, M.A., Ph.D., Regent's Office, Albany, N. Y.:

"Mr. Halsey's paper is certainly the ablest and strongest presentation against the adoption of the system that I have ever seen, and since reading it, I recognize as never before, that 'linear measures are tied to the past.' Still I cannot agree that they are 'irrevocably' tied. The cubit was once largely used in the civilized world, but we are not now tied to the cubit. That the change would be gradual, that it would cause uncertainties and confusion, no sane man can doubt. Indeed in many remote districts, people still reckon money in shillings and pence, but that fact is no argument against the use of our decimal system of coinage.

"As a teacher, representing the interests of children, I am specially anxious for the adoption of a simpler system of weights and measures that will relieve the memory of a burden arbitrary and useless and therefore intolerable.

"If it should be deemed best to retain the foot and the inch, why should we not adopt the litre and the gramme?" †

From Mr. C. A. Bates, Head of Assessment Division, Treasury Department, Washington, D. C.:

"I have read Mr. Halsey's paper and have been greatly impressed by the strong common sense displayed therein, especially in the matter of the increased labor of calculation by the metric system as compared with that required under the present system, which, although designated 'binary,' is not inconsistent with the use of decimals, as is the case with our monetary system, in which we have silver half dimes, quarter dollars and half dollars, and gold quarter eagles and half eagles.

"Attention is called to the relatively large number of figures needed to express taxable quantities in litres as compared with that required in stating those quantities in gallons and tenths of gallons as set forth in my tabular statement on page 70 of testimony before the Committee on Coinage, Weights and Measures, last February.

"I note that Mr. Halsey, in paragraph 8 of his paper, cites 'Mr. Bates' as of the opinion that 'a year or two' is all the time needed to make the change to the metric system, and refers to page 92 of said testimony for his authority.

"I would say that I am not the 'Mr. Bates' referred to on page 92; also that

* *Foot-note by the Author.*—Refer to the discussion of the use of the system in commercial literature and correspondence, paragraph 80. It is to such use only that the cited consular reports apply.

† *Foot-note by the Author.*—Many of our units are obsolete, or practically so, and our teachers, by including them and exercises on them in school text-books, create for themselves the very burden from which they clamor for relief.

my views in this matter of time as well as other important matters, will be found on pages 64, 69 and 70, of said testimony. My testimony on page 64, is to the effect, that if the metric system is adopted by Congress, it should be made on an *eight year's* notice.

"To illustrate the facility with which the binary system of gallons, half gallons, quarts, pints and gills, as applied to the liquid, distilled spirts, the tax on which is the principal source of the internal revenue of this country, blends with the decimal system, the Commissioner of Internal Revenue, with whose views this letter accords, will mail to you a copy of the U. S. Internal Revenue Gaugers' Manual consisting largely of tables in which the binary and decimal systems are happily blended."

From Mr. C. H. Tittmann, United States Coast and Geodetic Survey, Washington, D. C.:

"Mr. Halsey mentions my name in his paper and implies that my statement in regard to John Quincy Adams' attitude is incorrect.

"Mr. Adams was simply referred to by me because while he opposed the adoption of the metric system, as every one knows, at the time when his report was written, he nevertheless used language in regard to it which I think justified my statement that he considered it an ideal one. Listen to this which is quoted from him: 'If man upon earth be an improvable being, if that universal peace which was the object of the Saviour's mission, which is the desire of the philosopher, the longing of the philanthropist, the trembling of hope of the Christian, is a blessing to which the futurity of mortal man has a claim of more than mortal promise; if the Spirit of Evil is, before the final consummation of things, to be cast down from his dominion over men, and bound in the chains of a thousand years, the foretaste here of man's eternal felicity; then this system of common instruments to accomplish all the changes of social and friendly commerce will furnish the links of sympathy between the inhabitants of the most distant regions; the metre will surround the world in use as well as in multiplied extension; and one language of weights and measures will be spoken from the equator to the poles.' " *

DISCUSSIONS CONTRIBUTED IN MANUSCRIPT.

Mr. Gus C. Henning.—On rising to discuss the paper before us, I desire to preface my remarks with the statement that to me personally it makes no difference, whether the metric system is

* *Foot-note by the Author.*—Mr. Tittman has unearthed another of the few inconsistent expressions of approval to be found in Mr. Adams' report, and to which I referred in paragraph 6. Read my last quotation from Mr. Adams, in which he condemns the metre, the kilogramme and the litre in succession. *By no stretch of the imagination can Mr. Adams' report, taken as a whole, be looked upon as an indorsement of the system.* The two sentences which immediately precede those quoted by Mr. Tittmann read as follows; "It has undergone various improvements and modifications. It must undoubtedly still submit to others before it can look for universal adoption."

adopted in this country, as the legal standard or not. All I can say is, that when I desire to do my work of calculation and designing, with rapidity, I frequently use the metric system by preference, but when I put my work into the shop the drawings are figured in inches, and fractions thereof, because this is the measure in common use in this country.

In paragraph 33 the author chooses to quote a statement made by myself four years ago, page 600, vol. xviii., *Transactions*, which he tries to make out incorrect. When making the statement I did not say that taps, dies, drills, etc., made to the English or United States standard were not used on the Continent, as I took for granted that it was a well-known fact that all these tools were bought in the United States and England in large quantities, but what I meant is that they are never measured by workmen by the English standard; they are always used according to the marks thereon by which they are indicated on the drawings. It is not a fact that the English standard is used in shops on the Continent as it is used in England and the United States for purposes of measurement, and that is all we are talking about. Let me ask, does anybody in this country pull out his scale or micrometer to measure the dimensions of taps, dies and drills before he uses them?

I must repeat that in none of the many shops I had the occasion to visit on the Continent, did I ever see or know to be on hand (except in a tool room) any English standards, and in the French shops I never saw anything but the metric standards. Let me explain, however, how the matter works in countries which frequently use both the inch and metric standards, merely because Great Britian and the United States still use the inch standard. Recently I sent my drawings figured in inches to Continental manufacturers, who executed the work, delivered at my office in New York, duty paid, at just one-quarter the price and in one-half the time at which two American manufacturers had offered to furnish it. Reasoning from these facts in the manner the author has assumed throughout his paper, I am prepared to conclude " that the use of the double standard increases the cost of the work very materially and also causes great delay; and also that even the Krupp Works are not using the metric system, but are actually using English measures as their standards. Therefore the metric system is of little value as it is not in universal use in Germany, for it is not in general use in the largest of German steel works." Q.E.D., and as a proof of the difficulty of using two standards in any work, I will quote the author, paragraph 65, by saying, "This illustration is contemptible in its littleness."

Not one of the statements in this paper show that the reporters quoted had seen any English standards used for purposes of measurements in shops or by tradesmen; and even Mr. Hess merely says, paragraph 29, that "We have occasionally found that men in our shops have made use of their private Rhenish foot rules."

Well, we know that all cranks are not dead yet. And while Mr. Hess admits that he knows nothing about custom in France, he cheerfully volunteers his belief "That similar conditions exist there, though not to as great an extent." Think of the great value of this testimony to strengthen the author's argument.

In reference to the remarks on the "Persistence of old units in Spanish America," I shall quote the statements of an American engineer who has lived and worked in several Spanish American countries for a period of ten years:

In answer to your inquiries concerning my experience with the use of the metric system of weights and measures in the various countries of South America with which I am familiar, I take pleasure in stating the following:

From early in 1886 for about 4½ years, I was employed as first assistant in the Argentine Meteorological and Magnetic Observatory where, of course, we used only the metric system. In our work, we employed many sub-computors and observers of moderate attainments, and I found that they readily understood and worked efficiently and rapidly with the metric system. In my opinion, the absolute accuracy required in our work could hardly have been obtained by any other system with the help we had.

Apart from the Government and purely scientific work, I had abundant opportunity and occasion to know of the Civil Engineering practice of the country, and in this as well I found that the metric system was used to the exclusion of all others, not only in the field, but in the office and draughting room. With the metric system, engineers of all nationalities, met upon common ground and worked together in perfect harmony of understanding. Our old chain with its links and tenths was replaced by the steel tape with its metres and centimetres and the unit by the kilometre, although in cross-pampa travelling on horseback the campesino, or countryman, still reckoned distances by the day's journey (jornada), hour or league, each of variable length and used simply on account of the familiarity of the terms.

Linear measurements, I may say, were made generally metrical even at that day when the use of the metrical system was a comparative novelty. In the centres of population, usually coincident with the centres of commerce, the metric system could be said to hold sway. In the ordinary commerical transactions, liquids were bought and sold by the "litro," and dry articles by the kilogramme or "kilo," while the "metro" was in common use, though the variable "vara" was not entirely excluded. In the sale of goods over the counter by retail, the "vara" out of respect for its age as a term, may have been used extensively, but at the same time, goods were valued by the metre, and the "vara" sold or bought meant only so much of the metre used as the standard, just as an "arroba" of corn or potatoes meant a certain number of kilos weighed out by a metric weight, so that no matter what term was used, the metric system determined the quantity. An "arroba" in this case always means 12 kilos. In land measurements the "cuadra," or square, was formerly used. This term, like the "vara" had a variable meaning dependent upon locality, so that in order to prevent confusion the metric "cuadra" or square of 100 metres side was used throughout the republics, and gave exactness to the meaning of an old term.

Leaving the Argentine Republic, I went to Bolivia where I found practically the same state of affairs. However, owing to the larger proportion of the Indian and other illiterate population of this country, the old terminology as well as the use of the old system of weights and measures in ordinary trade was more apparent. Among these people it is no uncommon sight to see commodities weighed out in a home-made balance with stones, nails, etc., used for the weights, simply for the want of something better. I feel confident that even the ignorant Indian would gladly adopt the metric system could he only gain access to it upon equal terms with his inexact system, which circumstances force him to use.

In Peru and Chile, I was closely connected with railway work, mining and chemical analysis, for more than six years. I can testify to the fact that the metric system was used in assaying, and other laboratory work, and in most departments of railway work. In the shops of the railways with which I was connected for a time, it is true, the English system of measurements was used, because nearly all of the engineers and mechanics, and machinery were of American or English origin, and the shop practice was imported with them. Outside of this department, however, we used the metric system almost exclusively.

In the ordinary transactions of life, I may safely say that the metric system was the one in common use, in spite of the preponderance of the old terms in ordinary language.

Yours very truly,

(Signed) R. C. ALEXANDER.

N. Y., December 2, 1902.

The foregoing will again show the humorous use by the author of statements quoted in the paper, and that they are painted with all the colors of the rainbow. The deponents and the author all fail to see that the use of current terms really refers to metric weights and measures, and that the opinions are based on bias. They should be accepted with many grains of salt, indeed with crystals of rock salt, and then only after much reflection and complete verification.

In paragraph 40 is another instance of the use of old measures of length in Peru and Venezuela, where according to the testimony of Messrs. Iglehart and Dodge, the yard tack upon the ribbon counters are still in use. These gentlemen do not however tell you that the ribbons are sold by the metre and charged for at that rate, while at the same time they were measured by the yard. Don't you see that this method of procedure produces an extra ten per cent. profit to the haberdasher? Messrs. Iglehart and Dolge failed to see the real humor of this practical joke or profitable Yankee trick, and the author can only find in their statements the essence of truth, profound knowledge and intelligence!

You see Mr. Iglehart merely quotes from memory; see paragraph 39, fortified by our Peruvian Consul-General who had probably not yet discovered during his short period of service the common application of old Spanish names to the metric measures. As to the use of the metric system in Mexico, I know that the Compania Metallurgica Mexicana uses the metric system entirely, and all materials purchased in the United States must be invoiced and marked and inventoried on the metric system.

The fact that rag-carpet weavers and seamstresses in this country measure yards by the distance from the tips of their noses to the palms of their hands; or that tradesmen measure bushels of farm products by any old basket; or that grocers and butchers weigh their goods by any piece of iron with numerous holes therein, is not proof that the English system of weights and measures is not the standard in common use in this country.

Just such facts as given in the foregoing form the foundation of the author's arguments, and while no one will deny that old weights and measures remain in use in countries even long after they have been declared illegal, the fact of their use for unimportant purposes should not be used as a valid argument that other standards are not those in actual general use.

In paragraph 30, Mr. J. H. Linnard, Naval Constructor, U.S.N., is quoted as saying: "that two yards, one of considerable importance at Flensburg, and one at Hamburg, still use the English system of measurement for their ships' work." Neither Mr. Linnard nor Mr. Halsey, however, gives reasons why the English standards are there used by preference, the latter however using this as another proof that the metric system has not been very generally introduced in Germany, and that it in fact meets with strong opposition there.

The reason why these shipyards use the English measures is this: they use English shapes and ship fittings almost exclusively, and to a large extent are copying English designs. The reason why they use English shapes and ship-fittings almost exclusively is that they can buy them cheaper and obtain them more promptly in England than in Germany, because there are very many manufacturers of these articles in England, all competing; while in Germany there are but very few, most of whom deliver their entire product to government and other ship-yards. Under these circumstances it is plain that the English standards are more convenient to the two shipyards mentioned.

The author states, pragraph 71, that Mr. Linnard "learned his profession in France," but fails to state that previous to that time he had studied and used the United States standard during at least twenty-three years, and was in France but five years. I am sure that Mr. Linnard never tried to really use the metric system or become expert in it, because he knew that in a very short time he would again return to the United States, and then again and ever after use nothing but the United States standard inch scale. If Mr. Linnard's testimony be compared with the arguments given in Balfour Stewart's "Elementary Physics," it will be found that they are almost identical. And this is the eminent authority on whose testimony the author bets his bottom dollar!

As long as the metric system is not introduced in England, just so long will the English standard be used to some extent in Germany and other countries, which is no proof, in any sense of the word, that the metric system is not in general use in them, as the author tries to make it appear.

In paragraphs 8 and 12 the author presents a horrifying picture of the continuing use of ells, pounds and yards in the textile industries, alongside of the metric system. He does not, however, explain that this condition exists because of the preponderance of English machines and materials used in this industry. As Germany draws a large proportion of these supplies from England, it is clear that they will adhere to these terms until England also adopts the metric standards. Moreover, a pamphlet containing extracts from the *Textile World*, just laid before us, shows that among forty-five American cotton and worsted mills, twenty-one are strongly in favor of the adoption of the metric system, eighteen are against it and six are non-committal, while those in favor of it state that they are so in order to get rid of the existing confusion.

The author, in order to impress upon his readers what terrible result the introduction of the metric system would have on textile industries, chooses to translate "heillose Verwirrung," by "ungodly disorder," instead of using the correct words, "irreparable confusion," or its usual meaning, "great confusion."

The author does not give a simple explanation of the persistent use of different standards of measuring still found in local districts in Germany and France, which has found a parallel in our anthracite coal fields.

The manufacturer who looks after the conversion of measures buys and sells by metric system, and whenever he converts the measure of the laborer's work into his selling measures, the benefit of the odd fraction or remnant does not fall to the laborer, but to the capitalist.

In our anthracite fields the Pennsylvania law makes it compulsory to weigh coal by United States standard weights, and failure to do so is punishable by a fine of one hundred dollars per day for each and every offence. Nevertheless for twenty-seven years the coal barons have used the standard of a mine car heaped up with coal, without weighing the coal, and continue to do so at the present time. The author forgot to mention the use of this standard of weight in a country which, as he must admit, uses the United States standards of weight universally. He will, perhaps, also now understand why the old standards are still sometimes adhered to elsewhere.

In paragraph 53 is given the famous argument of the anti-metric fraternity, bewailing the fate of the poor forlorn farmer because he hasn't any metric table of bolt dimensions and table of equivalents.

This paragraph should, when honestly put, reads as follows: A farmer breaks a bolt and wants to replace it. What does he do? He takes the broken bolt and looks over his stock to see whether he can match it by appearances. If he can do this, he tries it in the hole from which the broken one was taken, or tries the nut on it; if it fits, then well and good. But, remember, farmers do not carry foot-rules in their trousers pockets, jeans or bootlegs.

If the spare bolt does not fit, the farmer betakes himself to the nearest supply store and asks for a bolt "like this." He does not care whether it is $\frac{3}{8}$ inch, $\frac{11}{16}$ inch, $\frac{19}{32}$ inch, or anything else; he merely uses his old bolt as a gauge. The supply dealer may recognize what it is in diameter and thread. If he does not, he does not pull out his thread gauge and calipers, but he again uses the broken bolt and nut as gauges, and selects a new bolt and nut which will respectively fit into each other, and ever thereafter both farmer and tradesman will be happy without having asked, "Is this a metric or a United States standard bolt or anything else?

Now let us take up the argument of the table of metric equivalents of values of parts of inches, increasing by eighths.

This is again an extravagant misrepresentation of difficulties.

If the values of $\frac{1}{8}$ inch between 1 to 3 inches be given in the nearest quarters, or $\frac{1}{4}$ millimetre, not one of the figures given will vary from the true value by more than $\frac{1}{100}$ of one inch, which is a matter too small to observe by any person except he be provided with a micrometer caliper. The table will then read:

1	25.5	$1\frac{1}{2}$	38.00	2	51.0	$2\frac{1}{2}$	63.5
$1\frac{1}{8}$	28.5	$1\frac{5}{8}$	41.25	$2\frac{1}{8}$	54.0	$2\frac{5}{8}$	66.75
$1\frac{1}{4}$	31.75	$1\frac{3}{4}$	44.5	$2\frac{1}{4}$	57.25	$2\frac{3}{4}$	69.75
$1\frac{3}{8}$	35.0	$1\frac{7}{8}$	47.5	$2\frac{3}{8}$	60.25	$2\frac{7}{8}$	73.00
						3	76.25

In this shape the figures can be memorized by an effort, and they will be accurate for practical purposes. Let me ask the same question as the author. "Is not the point obvious at a glance?" All I can say is, "None so blind as those who do not want to see."

The sincerity of the arguments relating to change in screw threads, by which the author tries to prove the terrible confusion which would result thereby, is clearly indicated by the fact that one of the members of the metric opposition committee of this Society actually presents at this meeting a paper in which a new system of screw threads is proposed, because the old system has been found unsatisfactory. One of the strongest opponents of the metric system sees no objections to changing the standard system of screw threads, only, for Heaven's sake, don't let it be based on the metric system!

The author, paragraph 47, gives a woeful picture of calamity should pipe threads be changed. Never again could we fit one gas tip to a single chandelier in the whole country. What a terrible calamity! It would be necessary to rip out every piece of pipe in every house in the country. Woe be to us!

Now let us look at this in a less humorous manner. In exchanging a chandelier, the gasfitter tries the short pipe at its upper end on the nipple 3 to 6 inches long, and if the thread does not fit, he takes a new nipple of same length (no, pardon me, 75 millimetres length) and cuts on one end a thread like on the old nipple; on the other end he uses the die which fits the thread on the chandelier. Let us say this nipple costs ten cents, but the chandelier might cost \$75. Don't you see the great expense and hardship arising to the owner of the house. Why, it is plain. Again, think of the trouble and expense of fitting a gas tip in a similar manner.

Why, the nation would become one of night-walkers. How terrible!

The author fails to tell us, however, that a ½-inch pipe measures 0.623 inch inside, and 0.840 inch outside dimensions. In fact, all pipe dimensions must be given in decimal fractions of inches to three places, because there is no such thing made as a pipe measurable by any kind of a foot-rule with its beautiful symmetrical and divisible parts.

In paragraphs 67 to 70 are arguments to prove that it requires a smaller number of figures to write and use in calculation of dimensions given in the United States standard. For this purpose he uses the simplest figures on the foot-rule, and the largest in the metric scale. He starts with a conversion of even dimensions of inches into the decimal parts of the metre. Not once does he show the results of conversion of even metrical divisions into inch values. Then he uses the even 8 feet, and also 8½ inches in calculations, converting them into millimetres.

Let us examine the foot-rule divided into inches and sixteenths, and compare it with a similar length of the metric scale, which is equal to 305 millimetres within .0008 inch. This foot-rule contains 192 even divisions; the metric scale 305. It requires 861 figures and lines to write these 192 even parts of the foot-rule. However, it requires but 831 figures without points, lines or commas to write the correct values of the 305 divisions shown on the metric scale. At this rate it would require 1,367 figures and lines to write 305 divisions of the one-foot rule.

Assuming, however, that the foot-rule be divided into inches and hundredths of inches, then it will require in writing only 303 of these divisions, no less than 1,183 figures and decimal points. To write all of the 1,200 divisions it would require 4,752 figures and decimals; while if the 305 millimetres were given to the nearest quarter, or making a total of 1,220 divisions, would require but about 3,541 figures and decimal points.

This will show beyond any doubt the vast superiority, convenience and economy of time in the use of the metric system.

As this proves beyond question of a doubt that fewer numbers and marks suffice for writing the exact divisions of a part of the metric scale equal to a single foot of the United States standard, it is simply an absurd misrepresentation to state that fewer figures will be used in calculation, using the latter scale.

The author states, paragraph 67, that " in English units these dimensions "between 4 and 100 inches" can often be expressed by a single figure." What has the author to say about the thousands of intermediate values in sixteenths of inches? About these he is profoundly silent.

In concluding I desire to emphasize that in the foregoing analysis of the author's arguments, I have carefully refrained from advocating by a single word the compulsory introduction of the metric system into the United States; all I desire to put clearly before the members of the American Society of Mechanical Engineers is the extreme position taken by the author.

Mr. F. A. Halsey.—Taking up Mr. Henning's communication, I quote:

> "Taps, dies, drills, etc., made to the English or United Standard . . . are never measured by workmen by the English standard."

Mr. Hess, who has been in the German Niles Works for three years, tells me that he has never seen the dimensions of English pitch screws named in Germany in any other way than the one used by us.

Mr. Henning's statement that "Mr. Hess merely says that 'we have occasionally found that men in our shops have made use of their private Rhenish foot-rules'" can only be interpreted by charitably assuming that Mr. Henning has not read paragraph 29. Note especially the statement by Mr. Hess: "Nearly universally, the carpenters and other building mechanics use the Rhenish inch." We are not limited to the statement of Mr. Hess regarding the use of old units in France.

The letter from Mr. Henning's correspondent who has lived in South America has the air of sincerity; but Mr. Henning needs evidence from more than one source to offset my cloud of witnesses. Note, however, that the Peruvian Consul-general does not agree with Mr. Henning's correspondent regarding common practice in Peru.

"Current terms refer to metric weights and measures." The use of these units in French and German textile treatises, the letters of M. Benét of Paris, of Mr. Ball of Barcelona, of Mr. Canby of Mexico, of Mr. Hess of Berlin, of the unnamed American engineer in Paris, and of the Collector of the Port of New York, make this explanation ridiculous. That Mr. Dodge could live in Venezuela for four years and not learn so simple a fact, is absurd. My informants are neither children nor fools. For what metric unit does the Rhenish inch stand? Note also the experience of Chandler and Taylor, paragraph 78, which shows that lumber and timber are not sawn to metric dimensions in Central and South America.

Messrs. Iglehart and Dolge said nothing about the yard tacks upon ribbon counters. That is my inference from their testimony. "Mr. Iglehart merely quotes from memory." What else is there to quote from, and from what else does Mr. Henning's correspondent quote? "Ribbons are sold by the metre and charged for at that rate, while at the same time, they were measured by the yard." Admit this to be true, and what does it show? Simply a confusion of old and new units, which is made the basis of a petty and universal swindle, made possible by the metric system, and which Mr. Henning regards as a practical joke.

Mr. Henning's explanation of the persistence of old units in German shipyards and textile mills exhibits a curious reversal of perspective. Of course there are reasons—the object of this paper is to point out some of them. It does Mr. Henning's case no good to point out additional reasons, but the contrary. It is the *fact* of the persistence that is awkward for him. What connection is there between "the preponderance of English machines and materials" and the non-English ells, the aune, the lea, the denier, the French inch, etc.?

"I am sure that Mr. Linnard never tried to really use the metric system or become expert in it." Of course that settles it; but is it possible to be a student in a French institute of technology for three years, speaking the French language using French text-books, and doing all one's school work in the metric system, of which the chief stock in trade is its simplicity without "really using" the system or "becoming expert" in its use? What becomes of the school children argument, if three years of this sort of work are not sufficient? Have we all to spend three years learning this thing? Mr. Henning's zeal for explanations exceeds his judgment. It is proper to add that Mr. Linnard is senior assistant to Chief Constructor Bowles. Mr. Henning will have to accept him as a competent witness, whether it pleases him to do so or not.

I know more about that *Textile World* vote than does Mr. Henning. *At no stage of the voting were there six non-committal votes.* The count is given in the reply to Professor Crosby, and includes some votes that have come in since the pamphlet to which Mr. Henning refers was printed. Adding together those who voted against the system and those who voted against the passage of the present bill until a more thorough investigation has been held, the vote stands *substantially two to one against the bill.* More significant still, this vote was the result of a letter sent to over 1,200 textile mills and textile men—seventeen votes for the system from 1,200 appeals sent out to an industry whose representativs go to Washington and represent that industry as demanding it.

Mr. Henning's table of equivalents does not look to me to be so easily memorized as it seems to look to him, and if he will add the sixteenths, which must be done, it will look less easy still to both of us. It has, however, the fatal defect of all approximate tables—they are accurate enough for some purposes, but not for others. This table is accurate enough for bar iron, but not for reamers and many other tools. Reamers could not be ground to his figures nor could they safely have the figures stamped upon them. For accurate work we must have an accurate table. That is, an approximate table is only an additional or supplementary table which does not simplify matters, but on the contrary, makes them still worse, and, moreover, opens wide the door for limitless mistakes.

Mr. Henning completely misrepresents my illustration, based on a supposed change in gas-pipe threads, paragraph 47, which nowhere says or implies that "it would be necessary to rip out every piece of gas-pipe in every house in the country"; but, on the contrary, says "the gas-pipes in the ceilings of our homes would keep the old system alive for fifty years," which distinctly contemplates that the pipes shall remain. I can only charitably assume that he has read this paragraph with his eyes shut. The supposed use of transition fittings has been considered in paragraph 47. "The transition fittings must be made. . . . The tools and the equipments must be preserved." That is, we shall have two standards of threads and fittings and a third set of transition fittings on our hands as long as existing pipes endure. Our existing fittings are numerous enough, but they must not only be duplicated in metric fittings but more than duplicated in transition fittings. It is easy to make light of a transition nipple, but the proposition involves transition ells, tees and other fittings. For each straight tee of which we now have one, we should require during the transition period the following combinations:

M M	E E	M M	E E	M E	E M
M	E	E	M	M	E

For each simple reducing bushing we would require four combinations thus: English inside and outside; metric inside and outside; English outside and metric inside; and English inside and metric outside. For each plain ell that we now have we should need three and for each reducing ell, four. If the reader will go to a pipe-fitting factory or store, note the number of fittings necessary to make an assortment and reflect that during this transition period this number will be multiplied by not less than three and probably by four, he will recognize what Mr. Henning's playful suggestion grows into. I have often said, and I believe it to be true, that all the advantages of the metric system combined would not recompense us for the confusion of changing our standard of pipes and pipe threads alone.

The fact that actual pipe sizes are other than the nominal sizes is a favorite citation of the metric advocates but it has no application whatever. *The trouble lies in changing an established standard.* Entirely apart from the discussion of this subject, a friend once remarked, "Our pipe and pipe-thread standard is, *per se*, about as bad as it could be, but, established as it is, the man who would attempt to change it deserves to be hung."

The discussion of the number of figures required by the two systems may be continued forever. Mr. Henning's count is unfair because it assumes that all dimensions are used with the same frequency, whereas, in reality, we avoid fractions and use round sizes wherever possible. Relatively speaking, few fractions are used for dimensions above 12 inches and above 18 inches they practically disappear. In small dimensions, sixteenths are used much less than eighths, thereby saving a figure. This basing of "proof" on things which we are supposed to do, but which in point of fact we do not do, is thoroughly characteristic of the metric case. *The use of round dimensions does not reduce the number of figures with the metric as it does with the English system.* It requires as many figures in machine-shop practice to write an even metre (1,000) as it does one metre plus one millimetre (1,001).

Mr. Henning's assumption that his little count has proven "beyond any doubt the vast superiority, convenience and economy of time in the use of the metric system" is really amusing.

Finally, what reasons has Mr. Henning given to show why we should adopt the metric system? Except for the count of figures just discussed, *none.* What has he said to prove that the adoption of the system does not involve the destruction of all mechanical standards? *Nothing.*

Mr. Geo. W. Colles.—"Children cry for the metric system!" Such is the burden of the tiresome refrain which is now being shouted through the land with renewed vigor, and by whom? Not—so they tell us—by a little coterie of propagandists, but by a chorus of commercial men, manufacturers, college professors and engineers both singly and in groups, by resolutions of clubs and societies. With such an apparent array of forces against us—not to mention the whole of Europe—ought we, the mere handful of us who think differently, not to feel very small indeed and utterly quenched by so great a body of authority?

It has, however, been wisely observed that *Vox populi vox Dei* is a dictum not to be trusted in science. But to call the present agitation a *popular demand* for the metric system would be ridiculous, for all the evidence thus far presented bears the unmistakable earmarks of "testimonials" of a private nostrum—a miscellaneous assortment of endorsements collected here and there, by hook or by crook, and the majority of which are, as Mr. Halsey pithily remarks, mere offhand opinions of the "It's a good thing, push it along" order, which, as against *reason, logic* and *common sense,* are of no weight whatever.

The queerest and most inexplicable part of this performance is, however, that so many are found to *endorse* the metric system, and so few to *use* it. If they want it, why don't they use it? Why, for instance, doesn't Mr. Westinghouse employ it exclusively in his numerous manufacturing industries—especially for electrical apparatus, to which it should be peculiarly adapted? Why don't the civil engineers get together and resolve to use it in their professional work, their drawings, specifications and estimates? This at least would make a good *beginning,* would show by the force of example what could be done. The answer is, as Mr. Halsey gives it, "Because they cannot; because measures of length, etc." *They have tried it and failed.* (See *Transactions,* vol. xviii., page 576.) In not one single case have they succeeded. So, having failed in their own efforts to introduce the metric system, they seek the aid of compulsory laws to force it on those who do not want it.

It is deserving of note in this connection that while innumerable *other* standards of measurement, whether by gradual spread, or by definite agreements of manufacturers, have reached and are reaching a state of general acceptance and universality in this country in not one single instance has the metric system or any of its units become the accepted standard for anything, either in this or any other country during the 110 years of its existence, save by governmental coercion, and then only partially and through acts of tryanny which are not and *never will be,* I thank heaven, a thinkable possibility in this free country of ours.

It is naturally a satisfaction to me personally to note that at least one person has come independently to precisely the conclusion expressed by me in my paper of six years ago. The conclusion I particularly refer to is (*Transactions,* vol. xviii., page 587):

"18. That . . . adoption has been merely nominal in most or in all cases, except France; that even there the old names and the old values are still in daily use, and that the Government finds itself powerless to contend with them."

The discussion of my paper brought out a strong dissent to this conclusion, to which I replied by citing further examples (Discussion, pages, 607-609), concluding with the following sentence:

"If any one would take time to look into the matter for the purpose of overthrowing the partisan evidence of the metricists, I haven't a particle of doubt a mass could be collected which would turn theirs to ridicule.

I think it was Darwin who remarked that false observations are always more persistent and harder to overthrow than false theories, a saying of which this case is an excellent illustration. The statement that the nations of Europe are absolutely and exclusively metrical has been so repeatedly and forcibly made by its partisans, that even the more skeptical among us have come to treat this as a well-established fact. But nothing could be more illusory.

For a vindication of the sentence above quoted, I need now only refer to this paper. I am glad to see some one besides myself *has* undertaken to collect evidence on this question. But while I think the author's evidence does plainly turn the mere negative statements of the metricists to ridicule, let it be remarked that even this evidence is of but a very fragamentary nature (I don't suppose he claims it to be anything else), and does not pretend to tell the whole truth.* As regards myself, I may say that it was only after I had written my paper, above cited, that the evidence referred to

* Mr. Colles is exactly right. My inquiry is such an one as it is possible to conduct by correspondence during spare moments, and with the Atlantic Ocean between the inquirer and the thing inquired into. If such an inquiry will develop such facts as these, what may be expected of an investigation made upon the ground by one who should look, seeking to find instead of seeking not to find? F. A. H.

began really to pile up and accumulate in such masses that I was obliged to abandon the task of compiling it for lack of time.

Such evidence as is here collected is open to any one having a knowledge of foreign languages and access to foreign books and (especially) periodicals, so that he who runs may read. Nobody, for instance, can pick up a South American journal and examine the market reports without noticing that the vara, fanega and arroba are as commonly and universally used to measure commodities in those countries as the foot, bushel and pound are with us. The fact that metres and kilogrammes also show themselves counts for nothing—at least nothing in their favor. It merely shows that confusion has been either introduced or worse confounded by them. As for Germany—aside from books and papers, I have frequently seen such terms as "zoll" (inch) and "pfund" (pound) even in *patent specifications*, issued by the Imperial Patent Office—the strictest in the world, and which regularly requires unused and unusual terms to be eliminated. (These facts are well within my personal knowledge and observation.) If such terms, *which are forbidden by law to be used*, even by the common people, are not simply not frowned on, but *actually passed by without comment in government documents*, it surely requires no Kantian deductive powers to conclude that they are terms in common use in Germany to-day, notwithstanding all the legislative thunders that have been launched against them, from 1868 to 1903. And if the *names*, then why not the *things?* I pause for a reply.

Now read the testimony of Mr. Henning (*Transactions*, vol. xviii., page 602):

> While the author has carefully rehearsed all attempts to introduce the metric system in Great Britain, the United States and France, he totally ignores the successful, rapid and peaceful change made in Germany, where it has taken only one generation to almost produce *oblivion of all previous systems*, in spite of his assertion that the English inch is still the only standard. Of course, when explaining to English-speaking persons what 19 millimetres (*sic*) means, he will always—remembering their unfamiliarity with the metric system—say about one inch;" but *they never use such measure, nor can one be found.* As to the common people, who from childhood hear nothing but metres and kilos, *they use no others*, in spite of the author's statements to the contrary, as I have learned through personal experience." [Italics mine.]

Some of the facts brought out by Mr. Halsey—such as that in Venezuela the metre is practically unknown—are news to me, I must confess, and go a step farther than I would have dared to predict. Note also (paragraph 38) that Mexico is still wallowing in the slough of "American measurements," and compare with Mr. Fairbanks' testimony (vol. xviii., page 596, 1896):

"The facts of the matter are that during the last year, the Republic of Mexico has adopted the metric system and enforced it. . . . As soon as the people saw that the matter was going to be enforced, they took it up. It was carried out by the government, and there is at present no state in Mexico where the people are not doing their business by the metric system and employing it for all their transactions. *My remarks are based on personal observation within the last two months.*" (Italics mine.)

"*Eppur si muove!*" It is evident that the Mexican railways are run only for the benefit of "gringos."

The author's suggestive picture of the civil engineers demanding compulsory use of the metric system for everything but land measurements, and the mechanical engineers for everything but screw threads, is paralleled by the laws of some "metric" countries, *e.g.*, Senegambia, where its use is obligatory for everything except *fruits*. Loin-cloths might also have been advantageously excepted.

There is one point with relation to the legislative aspect in this country to which the author does not give the prominence he should. I refer to the position taken by our Congressional Committee on Coinage, Weights and Measures. This committee, instead of being, as it should, an impartial body of judges sitting to consider fairly all measures submitted to it and adopting the most practicable ones, has been consistently a seat of the metric propaganda from the beginning till now. The last bulletin published is only one of many, all of the same sort. The fact that the testimony is all one-sided may be taken as indicating simply that some sort of "Pride's Purge" has been administered to keep out the testimony on the other side—for to pretend that none exists is absurd. It has been simply ignored, that is all, and the arguments against the metric system, the report of John Quincy Adams, and the published confutations of partisan allegations simply smiled out of existence. (See, for instance, the pretended canvass of government officials in 1896, which embraced only eleven replies (8 favorable) as against 23 replies (6 favorable) in 1877. Under these circumstances, it would be improper to conclude from the Committee's circular that the majority of those concerned really favor the measure. We have not yet heard the other side.

There is one statement made in the paper to which I must take exception. In the foot-note on page 4, the reports of Adams and Prof. Davies are linked together in one breath as representing "the only American investigations of this subject worthy of the name which have ever been made." It may doubtless be admitted that subsequent—*examinations* of these questions such as those of Dr. Barnard, the Franklin Institute, J. K. Upton, J. W. Nystrom, the Boston Society of Civil Engineers, etc., are not worthy to be called *investigations;* but the apotheosis of Professor Davies in this manner as the equal of Adams quite takes the breath away, and is unavoidably reminiscent of the nursery rhyme, "Said the flea to the elephant who are you shovin'." The report of Adams took *four years* of thoroughgoing and devoted attention and labor such as has never before or since been given the subject, and occupied, with the appendix, nearly 250 octavo pages. The report of Professor Davies consists of a reprint of Adams' report, Sir John Herschel's lecture, and about 28 16mo pages of introductory matter, largely a "me too" of Adams, to whose report, says Davies, "nothing can be added"—at any rate, it is certain he added little to it. The greatest merit of this report was that it made Adams' report accessible to the public.* Mr. Halsey completely omits mention of the numerous British reports and writings on the subject which, with this one exception (Adams), are of far greater importance and merit than ours.

Another point to which sufficient emphasis is not given either by the author of this or of any other paper is the question of decimal divisions. It is a curious fact that almost every new metrological scheme that has ever been put forward has embodied decimal relations of its units, and has based its claims to superiority chiefly on that fact. The point I wish to make, and on which I take my firm and emphatic stand is, that the decimal divisions are positively the worst feature, nay the absolute damnation of the metric system; and that, in fine, *no system founded on decimalism can ever obtain voluntary and general acceptance in any country.* The reason for this is simple enough, though it has been entirely overlooked by writers on both sides of the question. It is simply that the *primary* use of weights and measures is for *measuring,*

* As both the original and Davies reprint of Adams' report are now out of print, it is up to the Committee on Coinage, Weights and Measures to reproduce it. By doing so they would perform a far greater service to the public than by their endless pages of "testimony."

and *calculation* is only secondary. Now for weighing and measuring it is necessary that the units should be divisable into all the simple aliquot parts, 2, 3 and 4—but especially 2, and a division into *five* is practicably unusable. This reason is therefore based rather on abstract general principles than on the human constitution, and cannot be considered to be any different in one country from another. How strange, then, that all system-mongers should seek by decimals only to make their system look simple on paper, and entirely forget the fact that not a single unit of their own daily use is so divided!

Does it ever really occur to anybody that if tenths and hundredths of an inch were more convenient for general use than eighths and sixty-fourths, they would be *in* general use, instead of being restricted to the special uses where they *are* more convenient?

But for the decimal divisions, the metric system would perhaps have a fair chance of ultimate success. With the decimal divisions, the metric system must and will become extinct, notwithstanding all the laws of all the governments in the world, as all other decimal systems have done before it. The laws of nature are mightier. Let us not forget that.

I am glad to see that I have now at least *one* adherent of the position taken by me in 1896—that it is *impossible* to supplant our present weights and measures either by the metric or any similar system. You may "adopt" it and "adopt" it as often and as vehemently as you like, but *the thing cannot be done.* Not

> "Although the crowded orb should cry
> Like those who cried Diana great."

That is the Alpha and Omega of the whole question.

And finally, in all this pow-wow among scientists, engineers, learned societies, chambers of commerce, manufacturers, "practical" and unpractical men—where, finally, do the people appear? The people? Ah! we had forgotten. Ask the man on the street, for instance, whether he is in favor of the metric system? Go and ask farmers, housewives, laborers, clerks, business men the same question. Instead of answering for them, let me conclude with a parable—parables are often useful—drawn from real life. A certain regimental officer (the rank is no matter) of the Bluegrass State, the story relates, had a prize game-cock which had proved victorious over all antagonists, and whose owner went about, like Alexander, vociferously seeking new animals to conquer. A grizzled countryman offered to lay him a wager that his cock was a "no account" animal, and could not even fight a buzzard. The wager was accepted, and the two animals set face to face in the arena, being tied together by a cord attached to a leg of each to ensure a fight to a finish. The unpolished rustic, however, not precisely comprehending his cue, ogled his would-be adversary for a moment or two, and then giving him a melancholy wink, simply spread his wings and *flew away*—dangling Monsieur Chanticleer behind him.

The bearing of this parable lies in the application of it.

*Dr. Henry S. Pritchett.**—Mr. Halsey's article upon the metric system recalls to me a reply which Thackeray upon one occasion is said to have made to Carlyle. It seems that a company of literary men, amongst whom were Carlyle and Thackeray, in the course of after-dinner conversation, had fallen upon a discussion of the merits of Titian. One man spoke of his remarkable ability to draw, and remarked that this was an interesting fact about Titian. Another spoke of his sense of color, and that, said he, is another fact about Titian. At this point Carlyle, who was much bored by the conversation, broke in—"And here sit I," said he, "Thomas Carlyle, a man made in the image of God who neither knows anything about Titian nor cares anything about Titian, and that," added he, "is another fact about Titian." "Excuse me," said Thackeray, "that is not a fact about Titian, that is a fact, and a very much to be regretted fact, about Thomas Carlyle." Now the statements which Mr. Halsey makes as to the survival of old standards of weight and length in various countries have significance, not in showing the fitness or unfitness of the metric system; but, as showing the strength of conservatism, even amongst an intelligent people.

Mr. Halsey's arguments may be grouped under two statements:

(1.) The metric system, even in the countries where it has been officially adopted, has not wholly displaced old standards in certain industries.

(2.) The old standards, and particularly the standards of length, are so interwoven with the past that they can be replaced, if at all, only after long lapses of time.

With regard to the first of these arguments, it may be said that the reasons for the retention of old standards, as in the textile

* President of Massachusetts Institute of Technology. By invitation.

industries, for example, were beyond the control of any one country. Such industries would naturally be those in which conservatism would longest wait the adoption of a world system. Even under these circumstances the statements of Mr. Halsey seem to me quite out of perspective, and to be brought forward to prove a theory rather than to present the facts. Thus, in referring to the practise in Mexico, Mr. Halsey quotes the testimony of an American superintendent of motive power to prove that the English standards of weight and length are used in Mexico. It is difficult to take this sort of argument seriously, since the Mexican railroads running from the United States into Mexico are practically American roads, and their equipment is received from the United States. That they should use our standards is as natural, even as necessary, as it would be to use those measures for railroad equipment in the United States. If Mr. Halsey will go outside the mechanical department of these American roads he will find it impossible to do business, except in the metric system; and if the United States should adopt the metric system there would be no longer such survivals in Mexico. In other words, while in certain very limited industries the adoption of the metric system has been slow, these delays have in nearly all cases been dependent on international rather than national conditions, and in the aggregate are insignificant.

The second argument of Mr. Halsey, in which he objects to the metric system because there is something fundamental and sacred in the standards of the past, particularly in the standards of length, is itself an interesting evidence that human conservatism can outlive, in particular instances, any scientific evidence. The evidence which Mr. Halsey presents in favor of this theory is absolutely valueless. It is delightful to read Mr. Halsey's warning, "that measures of length are tied irrevocably to the past." This statement seems to me reactionary, and one based upon a wrong view of human history. Measures of length are arbitrary units, adopted for one reason and another by various peoples. When a people has become accustomed to one unit the change to another, even to a better or more convenient one, involves a certain amount of trouble which the ordinary citizen dislikes to take. The argument for the preservation of old and inconvenient standards rests on no other basis than this inertia of the general mass of mankind. In every movement which looks toward a simplification of the world's work some local tradition needs to be surrendered; and such surrender always calls out the protest of the ultra-conservative mind. The reader who is willing to study this characteristic of the human mind will find a very interesting parallel to Mr. Halsey's arguments in the discussion which went on for years over the adoption of a uniform day instead of a solar day, for the calendar year instead of the equinoctial year, and for standard meridians instead of local time. All of these changes involved the surrender of old and time-honored standards—standards which to many minds possessed the sanctity of divine appointment. Mr. Halsey's quotations of facts seem to me far from trustworthy, so far as I am able to test them from my own knowledge, but they are not half so interesting as the spectacle of a man who comes forward, as the representative of the twentieth century engineer, to maintain the thesis that the standards of length are irrevocably bound to the past, and that, therefore, the engineers must stay with them, also, I suppose, irrevocably bound to the past.

But, if I may speak more seriously, and I confess it is a little difficult to speak with entire seriousness concerning a paper like that under discussion, I beg to ask the attention of the engineers of this Society to the real questions to which, as it seems to me, an engineer will address himself in considering this problem, questions which are entirely lost sight of in such a paper as that under discussion. Briefly stated, the fundamental questions seem to me to be these.

(1.) Is a common system of weights and measures for the whole civilized world a desirable thing? If it is not desirable the discussion is ended, and there is no need to go further. If it is desirable the next thing to be settled is,

(2.) Are the benefits to be gained by a universal system of weights and measures sufficient to justify a country (say the United States) in surrendering its present system to adopt such a world system?

This is the really serious question. Personally, I believe that no qualified engineer (except the rare man of ultra-conservative tendencies) can look over the evidence without coming to the conclusion that our own system, or lack of system, is very poor, and that the proposed changes would involve far less expense and far less trouble than is generally believed. No one pretends that this change can be made without trouble or without expense; but the question whether the complete adoption of the new system requires five or ten or twenty years is really of secondary importance, if in the end there is had uniformity of practice for the whole world. Such mechanical questions as a uniform measure of the pitch of screws will solve themselves when England and America come into the world system. The engineer who satisfies himself that the change is worth the making will then address himself to the question,

(3.) Is the metric system one fitted to answer the needs of the civilized world, and has it already gained such general adoption as to make it available as a world system? The data for answering the first part of this question are easily accessible; and I do not think it hard to show that action by the United States in adopting the metric system would soon lead to similar action on the parts of England and Russia, and thus bring about a world system.

I venture to suggest that these fundamental questions are those to which the engineer of to-day ought to address himself, rather than to considerations of secondary importance such as those raised by Mr. Halsey's paper. The difficulties of a mechanical sort to which he calls attention will disappear in a universal system; the transcendental questions which he discusses are of interest to the transcendentalist, but not to the engineer.

Mr. F. A. Halsey.—In reply to Dr. Pritchett, I would say that it is gratifying to find that the metric advocates are at last beginning to recognize that the changing of a people's weights and measures is a matter of serious difficulty. Against the flippant assertions of its ease heard in Washington, we may place Dr. Pritchett's admission, that in the textile industry the matter is "beyond the control of any one country." Mr. Henning has made a similar admission regarding old units in the textile and German ship-buliding industries; and Dr. Pritchett's explanation of the practice of the Mexican Central Railway is of the same kind. Here are two metric advocates who have advanced far enough to recognise that the question is of international magnitude. There is hope for both of them.

We have been told by Mr. Troemner, paragraph 36, that Mexico "made the jump at once from one standard to the other," which I have shown is not the fact. I am obliged to Dr. Pritchett for supplying an additional reason for this persistence of old units, but must remind him, as I have reminded Mr. Henning, that it is the fact of the persistence which is awkward for him, and that additional reasons do his case no good. When, however, was a special dispensation made exempting the operation of American-owned railroads in Mexico from the Mexican compulsory metric law, and how much application does this explanation have to the Mexican experiences of Messrs. Canby and Braschi, paragraphs 37 and 38.

"Outside the mechanical department of these American roads he will find it impossible to do business, except in the metric system." And by the testimony of Messrs. Canby and Braschi it is equally impossible to do business, except in the English and the old Spanish systems.

Nowhere have I said that there is anything sacred in the standards of the past. Linear measures are tied to the past by physical —not sentimental—ties.

"The evidence which Mr. Halsey presents . . . is absolutely valueless." I have shown the difficulties of this change to be so great that the old system is still in large use in France at the end of a hundred years, and Dr. Pritchett regards this showing as "valueless." What showing would he regard as valuable? What showing could be more valuable? Are we to enter upon this program trusting to his cheerful belief that these difficulties "will disappear," or shall we inquire into the experience of the rest of the world?

"The argument for the preservation of old and inconvenient units rests on no other basis than this inertia of the general mass of mankind." As an absolute failure to comprehend the fundamental elements of the subject, that statement represents the limit. The changes in the calendar and time systems to which he refers have no application, because no property loss nor sacrifice of any kind was involved in those changes. The adoption of the metric system is opposed because it will cost more than it is worth. The changes referred to cost substantially nothing.

To Dr. Pritchett's fundamental questions, I give my unqualified assent. Except for its appendix this paper discusses the second and third and not much else.

In my own estimation I have discussed this subject from the most practical of factory standpoints. In the estimation of Dr. Pritchett I am a transcendentalist. Obviously we shall not agree.

Finally, what reasons has Dr. Pritchett given for our adopting the system? Except his reference to the desirability of a universal system to which we all agree as we do to the desirability of a universal language—*not one*. What proof has he given that the adoption of this system does not involve the destruction of mechanical standards? Except the assertion that these matters "will solve themselves"—*none.* What has he said to show that the transition period will not last a century? *Nothing.*

Dr. A. E. Kennelly.—Mr. Halsey's paper is, I think, the strongest presentation that has been made against the adoption of the metric system, and against the Metric System bill now pending before Congress. It merits, therefore, careful attention, since a measure of such great national and international importance as the change of the official system of weights and measures in this country should not be made without the fullest consideration of all sides of the subject.

I regret, however, that I am unable to agree with Mr. Halsey. I have no personal knowledge of the methods of manufacture in the textile industries of France and Germany; but I do know that the use of the metric system in those and in other European countries is practically universal; that the metric system has supplanted in those countries systems as fantastic and antiquated as our own, and that the satisfaction given to the people by the use of the system in those countries appears to be complete. Assuming the evidence adduced in the paper to be indisputable, concerning the use of ells, leas, inches and skeins, in European textile industry, then the weight of this evidence is admissible to show that thirty years after the metric system shall have been adopted in the United States, there will be persons still clinging to inches, yards, quarts, perches, etc. But it would be inadmissible to indicate that the great mass of the people would not be using the metric system with benefit. There are quite a number of people, all told, in the United States, who speak only in foreign tongues. Nevertheless, the language of this country is indisputably English.

The text and burden of Mr. Halsey's paper are that "measures of length are irrevocably tied to the past." No one will dispute a reasonable interpretation of this bewitching proposition. Possibly there are a few people in the world who still use the sacred cubit of the Egyptians. To the past are irrevocably tied cruelty, superstition, trial by torture, and many social defects that the present has outgrown. It is no shame to the English-speaking race of to-day that it has inherited an incongruous accretion of weights and measures that an orderly minded person cannot defend. But surely it is a shame and disgrace to the race if, seeing a better system used by its neighbors, it makes no effort to change the medley for that better system on behalf of this and future generations. The very best system is only just good enough for the

United States. The bother of the change is no worthy argument for a progressive man. The change from the cumbersome pound-shilling-pence system of currency to our present decimal currency involved much trouble. It was vehemently opposed by many who clung to the existing order of things, for just the same reasons as those here discussed. Was the effort expended in changing not a good investment for the nation? It is a bother to throw away machinery in a factory because a new mechanical plant is superior. Yet progressive men do not hesitate to destroy old machinery when there is a clear advantage in supplanting it.

The real question is not whether a small useful minority of the people in the country, known as engineers of all classes, would be benefited by having their computations simplified through a change to the metric system; nor whether our same small minority would be bothered by workshop troubles during the transition; but whether the cost and trouble to the whole people, including engineers, is going to outweigh the positive advantages that experience on a large scale has shown to result from a national change to the metric system.

It is in evidence before the Committee on Coinage, Weights and Measures that the change to the metric system would save two-thirds of a year in the public-school life of each child in this country. This statement has not been challenged as yet. It means an enormous saving of labor to the community in the aggregate, disregarding entirely the additional saving of effort and time effected during adult life. This saving would pay for a very large amount of national bother in changing weights and measures. I believe that those who have visited metric-system-using countries, and have learned life in them, will admit that a reasonably conducted change to the metric system, led by the Government Departments, would lead to the ultimate full adoption of that system throughout the country, without entailing undue hardship to any citizens during the transition period.

Mr. F. A. Halsey.—In answer to Dr. Kennelly, I would like to ask why the metric advocates will never learn that the fitness of a decimal basis for a system of currency lies in the immense amount of adding to be done, to which there is no comparison in connection with weights and measures? One bookkeeper in a good-sized factory office will do more adding than the whole shop and drawing-office force combined.

Begging Dr. Kennelly's pardon, the claim that the adoption of the metric system will save two-thirds of a year in the public-school life of children *has* been challenged, and the persistence of old units in metric countries simply makes this claim ridiculous.

To the next to the last paragraph of Dr. Kennelly's contribution, I cordially subscribe; *but why does he not name those "positive advantages?"*

Mr. Samuel Webber.—I have read Mr. Halsey's paper with great interest, and fully endorse it in all points, especially in relation to the persistence of old customs in weights and measures in countries where the metric system has been nominally adopted, but I do not think that in the various arguments brought forward against any change from our present system, which we may call the "English" one, to the "French" or metric one, sufficient stress has been laid on what we may call the historical or international position of the question.

The metric system was one of the results of the great upheaval in France, at the close of the eighteenth century, which not only produced the French Revolution, but altered, or attempted to alter, about every landmark in reach of the revolutionary spirit. The French reformers not only changed the systems of weights and measures, but altered the names of the months, and attempted to abolish the Christian Era, redating the world from the first year of the French Republic.

France was for a time the dominant power in Europe, and, under the overpowering sway of Napolean, the metric system, was forced on the other countries of Continental Europe, how ineffectually, Mr. Halsey plainly shows.

Times have changed in one hundred years, and history has turned over a new page, and it is now the English race which is the dominant power in the world, if not, on the Continent of Europe. The English systems of weights and measures are spreading much more rapidly than the French ones, not only in her vast colonies, but through the great extensions of the power of the United States, and it seems a perfect piece of folly to attempt to turn back the march of progress, by adopting an inconvenient, and incorrect standard, which the French scientists "evolved from their own consciousness" a century ago!

So far as the decimal system goes, it is as much a "rule of thumb" as any other one, and was derived from counting the *digits* on the hands, and while very convenient for mere arithmetical calculation, is very inconvenient for all mechanical and constructive purposes. A carpenter, with a piece of string, which he can double, can cut any board, into halves, quarters or sixteenths, but when he has once got it into halves, it requires an elaborate spacing out with a pair of dividers, to get the pieces into five parts, and the division is not a natural one.

The "foot-pound" of James Watt is the established dynamic unit, and it seems folly to transmogrify it into such a jawbreaker as a kilogrammetre! The larger part of the steam-engines of the world are built on dimensions expressed in English inches, why upset all future constructions, by changing the measures to millimetres? The records of the geographical surveys of the United States are written in miles and feet. Why upset them all, by changing the standard measures to metres and kilometres?

All hydraulic calculations are expressed in feet and hundredths now, and we have all the advantages of a decimal system there for purposes of calculations. Why change it? Finally, the most valuable mechanical literature in the world is written in the English language and by English measure. Why destroy this or render it useless to future generations, except by translation and recalculation.

Mr. Fred. H. Colvin.—With the view of discovering whether the metric system had entirely replaced the native units of measurements, I recently spent a few hours in examining the government publication of Consular reports relating to commercial relations. The latest obtainable in bound volumes was for the years 1900 and 1901, and some of the discoveries are rather interesting as proving to the contrary.

Among the South American countries, which are held up as shining examples of knowing a good thing in the way of scientific measurements when they see it, I first found a report from the statistical office of Bolivia. The compiler had evidently overlooked the fact that this was a metric country, for railroad extensions were given in miles, mine products in pounds and tons, and the height of mountainous mines in feet.

Reports from Peru give lumber in feet, mine products in tons, while the detailed report of the superintendent of the Central Railway, concerning his road, gives everything in English measures.

Official reports from Uruguay are metric, but judging from the Consular reports, the native units are used in every-day life. There is also an exhaustive statement by the large house of Hufnagel, Plattier & Co., in Paysandu, Uruguay, as to the imports and exports, in which feet, kilos and pounds are hopelessly mixed.

From Venezuela there are reports from Maracaibo and Puerto Cabello, and not a mention of metric measure in the lot.

Consular reports from Mexico fail to mention metric measures in a single instance except when quoting government reports, indicating that its use is entirely official instead of popular. Railroad extensions and similar measurements are always given in feet.

Going to Spanish reports we find a quotation from a Valencia paper pointing out the increased competition of American fruit in their home market, and in France as follows: "Their oranges, apples, peaches, etc., reach Paris after traversing 6,000 *miles*, in a more attractive condition than ours after a journey of only 490 *miles*." Not kilometres but *miles*.

Consul-General Hay from Barcelona says, "that to gain this trade we must print catalogues in Spanish, as the Germans and English do"—but he entirely neglects to mention the necessity or advantage of having metric measures. Raisins are quoted in "arrobas" of 25 pounds each.

A report of navigation from Trieste, Austria, is in tons, rates in shillings per ton, battle-ships in tons displacements. Now these may be metric tons, and as the harbor improvements are given partly in feet and partly in metres, you can decide either way you like. Length of railways is given in miles, while the rates are in kilogrammes. The imports are in quintals, pounds and tons—makes a scientific system.

Belgium makes a bad showing for those advocates who think it can be assimilated in two or three years. Government reports are metric as a matter of course, but commercial houses give imports in pounds, cords and gallons. Crop reports in the Antwerp district are given in bushels and tons of 2,240 pounds. Lumber, however, is given in metres, while imports of cereals are in bushels. Another table giving the crops per hectare (2.471 acres), as follows:

Wheat (in bushels)	66.21
Potatoes (in kilogrammes)	38,911

(Note the inconveniently large figures owing to the unit being so small.)

Beet roots and tobacco are also honored with the scientific system, while all the rest must be content with the old units.

Imports of wood, both from America and other countries are given in cubic metres, while imports of rubber are in pounds. Both systems are used all through, lumber being given in cubic yards in one place.

Swedish reports give tables with pounds, metric tons, bushels, long tons, gallons, pounds and hundredweight. Other reports use kilos and pounds.

Germany.—In mentioning Agrarian legislation, bushels and hectolitres, English tons and metric tons all seem to have equal chance. Structural iron and steel are quoted in sixteenths and eighths of an inch. Textiles are quoted in hundredweights.

Italy.—Imports at Leghorn are given in hundredweights and tons, in other places in kilos. Exports are largely in pounds. Wine is quoted at so many " lire " per cask of 100 quarts.

In reports from Chile, Valparaiso, do not mention metric, but figures are given in pounds, tons and quarts. In Iquique prices are given in shillings per hundredweight, and Spanish quintals are also mentioned.

In the report from Bogota, United States of Colombia, yards and pounds are used, and there is also a quotation from a French paper regarding the mines of Muzo and Cosconeg, in which the distances are given in yards and miles. Still another report uses metric and English measures indiscriminately.

From Holland is the annual circular of the Hide, Skin and Leather Co., gives imports of hides in " piculs," and translates it into pounds, although official reports use kilogrammes. Harbor improvements are given in metres in some places, and feet in others.

But Japan leads them all in mixing up custom and science, the past and the future (perhaps). The official table of imports into Yokohama give a choice collection of piculs, kin, milles, tons, square yards, gallons, litres, square feet, gross, sho, etc., with piculs and kins in the lead, and litres notable by their scarcity.

Building sites are also mentioned as being rented for from 5 to 8 cents per " tsubo," which equals 36 square feet. No " centiare " about this.

The consul also says: " The Japanese have not abandoned their old weights and measures in favor of the metric system but have legalized the employment of the two side by side with the proviso that the Japanese weights shall be taken as the standard. The metric system has not come into general use. The engineers, mechanics and artisans of all kinds use the native measurements in preference."

These examples can be multiplied many times by those who have the time to examine the records. It should also be noted that these are not old reports but the latest obtainable. I may also add that no cases have been mentioned where there was any chance of confusing the English and metric ton, or other measurements as in tonnage of shipping in ports of metric countries. These have been assumed as all metric, although I have good reason to believe some of them are not.

The case is strong enough when we give facts that cannot be disputed and leave the doubtful ones all to the other side.

It has been assumed that consuls give the units in use in the country as there is nothing to indicate any translations, and consuls, as a rule, are not given to translating page after page of dry statistics. In the cases where native units are given, this is ample proof that there was no consular interference, for if translating it would be into English and not into native units.

These merely bear out the able presentation of the facts given by Mr. Halsey, and help to prove that the metric system is not practical enough to warrant the recommendation of this Society.

Mr. James Christie.—We must always expect a wide divergence of views on any subject not capable of exact or mathematical demonstration. The historical arena of polemics has been occupied by fierce and fiery disputes, too often on trivial subjects, much of which now seems amusing. On such matters as religion, politics, etc., we cannot expect, nor would it be desirable, to have a prevailing uniformity of sentiment, but in all affairs pertaining to national and industrial economics we should endeavor to obtain precision and uniformity of thought and action. Moreover, a prudent conservatism is always advisable, and better to bear the ills we have than rashly fly to others we know not of. Carlyle has said:

> All great peoples are conservative, slow to believe in novelties, patient of much error in actualities, deeply and forever certain of the greatness that is in law, in custom, once solemnly established.

Mr. Halsey's interesting paper imparts fresh interest to a subject that has been worn so threadbare in the past that it seems almost superfluous to revive the stale arguments that have been repeatedly advanced. The discussion might be considered closed, the question called for the ayes and nays to decide, to be or not to be, as the popular voice will determine. An excuse for the renewal of the argument, however, will be found in Mr. Halsey's paper, which attacks the subject from the standpoint of a quarter of a century subsequent to the legal and compulsory introduction of the metric system in the German empire. Mr. Halsey claims that there still lingers in certain of the arts remnants of the ancient systems that were formerly in vogue.

Thirty years ago, during one of the periodic revivals of the subject of the metric system, this being the earliest date that the writer of this discussion has any personal knowledge of, it will be remembered that exactly similar arguments were applied regarding the popular customs in France, urging that although the metric system had been enforced almost at the point of the bayonet, yet they had not been able to eradicate the old conflicting and cumbersome systems from France, more especially in the agricultural districts, where the wholesome bucolic atmosphere tended to preserve those primitive habits of society which are believed by some to be remnants of that Edenic condition when mankind was in its pristine purity.

Vain attempts are frequently made to enforce upon a crude society civilized methods for which they are not yet fitted. The enthusiastic promoter of civilization is apt to overlook this difficulty, an illustration of which is offered in the well-known story of the tropical planter, who, weary of seeing the negro laborers in the field bearing their cane burdens on their heads, endeavored to lighten their task by the substitution of a convenient wheelbarrow, the final result being that his slaves insisted upon carrying the wheelbarrow with its burden on their heads rather than alter their habits and wheel the vehicle on the ground.

Notwithstanding the arguments so frequently urged that our existing methods of weights and measures are a natural survival of what has been found fittest, we can point to numerous illustrations for which there can be offered no well founded reason, except that we have inherited them as a legacy from the past, and it is too much trouble to make a change.

What good reason can be offered for the continuance of the hundredweights and quarters interposed between pounds and tons still in common use in Great Britain although almost entirely obsolete here? The expressions are cumbrous and laborious to write and read or to multiply, and with our American tendency to take short cuts we wisely allow them to fall into disuse. What convincing argument can be offered for the continuance of the ton of 2,240 pounds? Inconvenient and useless from every point of view! The net or short ton, as we call it, of 2,000 pounds, is in common use with us both in our customs and our literature, and would have long since displaced its predecessor if the former had simply been made illegal. The tendency to change and simplify these matters is continually observed. We find it a growing custom to omit the use of the ton entirely. It is a common and growing practice to refer to large quantities even in many millions of pounds. When we ask, why burden yourself with so many figures? the reply is the uncertainty of what the ton means. If the ton was 2,000 pounds we would gladly use it, but the ton of 2,240 pounds involves more labor and more uncertainty in the knowledge of the result than stating the terms in pound quantities.

It has been said that, "whatever is, is best." This may be partially true in a broad and general sense, but it has no permanent or universal application, and the fallacy of the assertion is constantly being exposed. It rarely happens that any one system or method has all the advantages on its side. In fact, we frequently discern in methods that have passed into oblivion some most excellent features, but in comparing systems it is desirable to make an algebraic sum of the virtues and defects and retain the one that has the preponderance of redeeming features. In deciding on the merits or demerits of any system of weights and measures we must consider the benefits and the losses to be derived by every element of the community, and base our decision on whatever seems to yield the greatest good to the greatest number.

It will be observed that the examples offered by Mr. Halsey are chiefly drawn from the textile arts. In this manufacturing industry inherited terms probably enter more largely than in any other into the vernacular of the humblest mass of the people. As man's most imperative need, next to food, is clothing, the textile arts, next to agriculture, bear the most intimate relation to the masses of mankind. With these masses customs and traditions linger longer and are more difficult to eradicate than with the more highly organized conditions of society. The history of English legislation relating to metrology for many centuries indicates that measures relating to cloth and fabrics have always held a prominent place. The history of our American legislation on the currency is another illustration to the point.

Immediately after the adoption of the Federal Constitution, Gouverneur Morris and Thomas Jefferson began the agitation for the adoption of a national currency. The need of some coherent national system was very pressing, considering the heterogeneous character of the monetary units prevailing at the time, which were a jumble of English, French and Spanish coins, each with their own name and measure of value. Morris and Jefferson were both of one mind that the currency should be of a decimal character. They only differed in the details of the application. The arguments presented by these eminent men for the decimal system indicated that they fully realized its simplicity of comprehension and enumeration. The arguments against the decimal system were quite similar to those advanced by the metric opponents of to-day. I think this generation is all of one mind, that there was no mistake made in adopting our decimal system of monetary units. It was readily adopted, and received the approval of the intelligence of the country; yet, notwithstanding this, it is well known that over half a century and the old generation had passed away before the ancient terms fell entirely into disuse. Even the names clung when they had no significance except as a name, as illustrated by the long survival and various applications of the term "shilling." Yet in America a higher order of intelligence did and does prevail among the masses of the people than in continental Europe. We have no proletariat in the same sense as exists in Central Europe. The mass of the people more readily receive innovations and adopt improvements than is the custom with the older nations. Therefore, we could well understand why ancient terms and systems would cling more tenaciously with them than with us.

The retention of ancient terms or phrases in exceptional quarters bears little significance to this subject, from the point of view under discussion. On the other hand, we have the most convincing evidence that the metric system is now exclusively established in literature, in science, and engineering, and in the mechanic arts of France and Germany. We frequently find British units paralleling the metric in German and Belgian trade catalogues and tables. This is necessitated by the constant international exchanges, and is regretted by the manufacturers, who complain of the cumbrous conversion involved with the British units, as compared to the simple notation of the metric system. An eminent German engineer and metallurgist remarked to the writer a few years ago: "To us the advantages of the metric system appear so natural and self-evident, that the arguments offered by its opponents in Britain and America seem ludicrous; and our only wonder is that so practical a people as the Americans hesitate so long to participate in its advantages."

An American friend, recently returned from a tour of towns and villages in Germany, confirms the assertion that its adoption is now well established in the habits of the communities. Ancient terms sometimes remain, but they are found to apply to metric units, just as the old names for coins long survived with us. In the northern seaports the pound for weight is sometimes heard, but it is found that half a kilo is what is meant.

A singular feature of the case is that while the innovation is most urgently resisted here, among the mechanical trades, yet these seem to have been among the first to adopt the metric system in Germany, or at least in the southern states of the empire. This is sufficiently attested by numbers of German mechanics, who, leaving before the Franco-Prussian War of 1870, and before the system was made universally obligatory, assert that metric measures only were in use in the shops they left in southern Germany.

A distinguishing feature of the present time is a tendency to adopt quick methods and take short cuts to accomplish a desired result. Business letters are short and terse. The shortest words are preferred that will express the intended ideas. The gradual extension of phonetic spelling is removing unnecessary letters from words. The ponderous phrases and sentences of our ancestors are disappearing from our literature. We want the best, the most efficient tools, and expend much thought on reducing the manual movements of those who handle them. We waste little sentiment in preserving obsolete and inefficient tools, but consign them to the scrap heap with as little reluctance as we send worn out garments to the rag man. Our systems of weights and measures form the most important instruments at our command in making just and accurate exchanges. They should be the best to be obtained, and if found wanting they should with due care and caution be improved to conform to the needs of modern society. It is very true that it is a serious matter to alter existing standards, and the subject should not be entered upon lightly, but only after prolonged and careful study. It is doubtless quite feasible to make desirable changes in our present systems relating to mass and volume, without at all affecting the elementary principles on which they are founded. Inconvenient units of measurement could be abandoned and more convenient multiples might be adopted, but our National Congress, to whom the stubject is confided by the constitution, have always refrained from any action, because it was continually felt that the time for a radical change was not far distant, and until this positive step was taken it was not worth while to make any changes of present conditions. Reflect for a moment on what a convenient and useful method we possess in our Arabic system of numerals. How clear, concise, and expressive it is as compared to the Roman system, or any other ancient system it displaced. Each figure, reading from right to left, expressing a decimal advance; units, tens, hundreds, thousands, etc. Without this instrument our arithmetic and technical education and literature would be almost impossible. It is difficult for us to understand now that it took many centuries to graft this into our Christian civilization. Only after the art of printing was established, and its adoption became imperative, was the Arabic system completely adopted in Europe. The metric system is essentially an extension of the principles of the Arabic numerals from quantities in general to quantities in detail, to weights and measures. It is therefore essentially a decimal system so long as we have a decimal notation. If this should ever be changed so that either eight or twelve became the radix of our notation, then the metric system takes an octonal or duodenal form, with its fundamental features unchanged.

The question of our adopting metric measures as an international system has received such abundant expression during the last half century that we are now in a position to know approximately the views that prevail in the different elements of society. Among scientific men, meaning those who study or teach, but not directly connected with the industrial arts, the sentiment is almost a unit in favor of the system. This is amply exemplified by the actions of our scientific associations and the expressions of their leading members.

Among civil engineers it seems probable that a majority favor the system. In the class of mechanics and mechanical engineers it is probable that the majority would decide adversely at the present time, and not many years ago the writer of this discussion would have felt he was tainted with a mild form of heresy if he had ventured to advocate the doctrine among his professional brethren. We do not want to be in the ranks of a hopeless minority, and the knowledge of the existence of a goodly company among our mechanical brethren, and the gradual but constant increase in the numbers, serves to stimulate those who might otherwise be faint hearted on the subject. A confession of faith, with some reasons therefor on the part of the writer, might be offered in extenuation.

Some score of years ago, undertaking some literary work, which involved the preparation of a large number of tables, the calculations for these involved compounding the elements of dimensions and mass and occasionally of time. The arithmetical work involved was found to be much more laborious than was at first anticipated; but notwithstanding all the short cuts that offer themselves now to the ready reckoner, the work was found tedious and laborious, and only by the assistance of quick and skilful computers could the work be prosecuted with reasonable dispatch. Previous to this time I had not looked with any great degree of favor upon the metric or any other decimal system. The Greek and Latin prefixes, the foreign sounding nomenclature, and the unvarying decimal multiples, made no appeal except as interesting from an academic point of view. The conviction, however, gradually gained, and it was readily proved by example, that if we had the metric system of weights and measures to deal with instead of our own, that the labor would have been vastly reduced. The frequent conversion of vulgar fractions to decimals, to facilitate computation, the constant reference to conversion tables for weights and the ponderous multiplication or division involved in interchanging units of measure, were so burdensome that a feeling of envy grew for those who possessed the decimal system in its entirety, when these labors largely disappeared.

The metric system might be classed as being orderly, rational, and systematic, but the writer cannot endorse the sentimental nonsense about its "beauties," etc., sometimes expressed.

Facility of enumeration and computation is not absolutely inherent in the system. When arithmetical operations are to be performed on quantities devoid of fractions or qualifying terms, of course the arithmetical operation is the same under all circumstances, and cannot be altered. But when expressions involve various fractional divisions, or carry several quantities bearing non-decimal relations to each other, as is usual with weights and measures in our system, we frequently have to reduce the fractions to a decimal expression or convert them to fractional forms bearing common denominators; or we may have to convert the varying units of dimensions or weights into a common unit of measure, before we can satisfactorily complete the required summation. Then we have to reverse the process, and restore our gross sum to the various units of measure, to render them intelligible in our system. These operations are especially cumbrous and laborious when we are required to square or cube our linear measures to obtain measurements of surface or volume. All this interconversion is avoided when metric units are dealt with.

Still we frequently find notable exceptions in which arithmetical operations are performed with our quantities with greater facility than with the other. The apt use of favorable fractional terms by the skilful computer is frequently found to give the required result with greater facility than by the use of decimals. These are the exceptions that prove the rule.

Before wrought iron was so largely displaced by steel, by a happy chance its specific gravity was such that ten times the sectional area in square inches of a rolled bar exactly equalled its weight in pounds per lineal yard. This was a fortunate coincidence for the computer. At one effort he obtained the sectional areas and weights, and he usually required both. So useful was this that formerly manufacturers' tables gave weights in pounds per yard, although the yard was never a common unit of measurement in our shop practice. Latterly, as steel came into use, its specific gravity being 2 per cent. greater than its predecessor, the glory of the equation had departed, and tables were soon changed to weight per foot.

No exactly similar relation is to be found in metric measures; but, on the other hand, analogous examples of fortuitous relations between terms for mass and measure are much more common than in our system. For example, the established unit relation between the metric ton and a cubic metre of water enables us to get with slight effort the weight of any mass of material whose specific gravity is known.

Consider briefly the comparison between the two systems when working drawings are involved, and find whether simplicity of expression is not as apparent as facility for enumeration, in favor of the metric system.

An old and never ending trouble with our linear measures is the confusion frequently occurring between feet and inches. We can all recall errors or misunderstandings arising from the reluctance of the draughtsmen to place a distinct foot symbol between the figures for feet and inches. Some offices require all dimensions to be given in inches alone. The objection to this is that it imposes labor and chance of error in workmanship, as when measurements of several feet are involved the workman must make the conversion before he can make his measurements. The best practice is to place a distinct vertical dash for the foot mark, and a horizontal dash to mark the distinction between feet and inches. Counting these two dashes as approximately the equivalent of one figure, we can tabulate the number of figures required to denote given dimensions by either system.

As metric drawings, such as used for ordinary machine shop work, are figured in millimetres, the number of figures to be written is positively fixed by the length of the measurement.

In our system the number of figures is largely determined by the number and character of the fractions employed.

Approximate Dimensions in Inches.	Number of Figures Employed. Metric.	Our System.
40 in. to 390 in.	4	2 to 8
4 in. to 40 in.	3	1 to 7
$\frac{4}{10}$ in. to 4 in.	2	1 to 5
Below $\frac{4}{10}$ in.	1	2 to 4

Taking several mechanical drawings at random, the relative number of figures required by the two systems ran as follows:

Dimensions in inches.	Number of Figures Used on Drawings. Metric.	Average of Four Drawings. Our System.
Below $\frac{4}{10}$	1	2.22
$\frac{4}{10}$ to 4	2	2.35
4 to 40	3	2.83
40 to 390	4	4.05
General average	2.5	2.86

Consider the relative clearness and facility for interpretation of the drawings. Our usual scale of reduction down to 1 inch per foot ($\frac{1}{12}$ size), excepting $\frac{3}{4}$ inch per foot, are readily measured by the draughtsman or examiner by the standard rule, in the absence of the reduction scale, although not so readily in general as when the reduction is a decimal one. But when the plans are drawn to scales of $\frac{3}{4}$ or $\frac{3}{8}$, or, worst of all, $\frac{3}{16}$ or $\frac{3}{32}$ inch per foot, the perplexity begins, and generally results in the draughtsman searching for, or turning and twisting his triangular scale, to find the measure required. When we have the plans plotted by the surveyor for the building areas we propose to use, and he usually has sensible scales, 10 feet to the inch or desirable multiples thereof, then one's heart is gladdened at once, as no reduction scale need be sought. Our pocket rule usually applies to the case, and we obtain the desired dimensions with ease. So also with drawings from metric scales. Most of these can be interpreted at a glance by the standard metric rule, and any of them with little effort.

It is frequently asserted that mistakes could readily occur in drawings with metric units from a decimal point being misplaced. With mechanical drawings dimensioned in millimetres, the use of a decimal point would rarely occur. Only in drawings of great precision, or for very minute objects, when the millimetre had to be subdivided, would the use of a decimal point be required. When higher units than the millimetre were used on drawings, decimal points would be used as a matter of convenience; but how easy it would be to write all figures to the right of the decimal point in small figures, the same as we use for one of the terms of a fractional quantity, when all possibility of error would disappear.

It is urged by the opposition that the units are inconvenient, being too large or too small for facility of application in the workshop. I cannot answer this objection, as a faithful endeavor, extending over many years, has given no satisfactory evidence of any substantial difference between the practical conveniences of the respective scales. The decimal system is not capable of continuous binary division, and that is one of the disadvantages of a decimal notation, and offers a good argument for those who propose to make twelve the radix of our system. A duodecimal base has many unquestionable advantages, if it would be possible to obtain it without a revolution of a sweeping and destructive character. On the other hand, with a purely decimal system, the necessity of binary division is not so great as it at first appears. It practically disappears from technical literature, and remains largely a popular expression, as exemplified with our currency system, without any confusion or inconsistency.

In the mercantile transactions of life the metric system offers standard units of weight approximating about a ton, 220 pounds, $2\frac{1}{4}$ pounds, and $\frac{1}{4}$ pound, the latter a very convenient unit for petty transactions, which is lacking in our system, as the ounce appears to be an obscure unit in the popular mind. It is generally conceded that the system, so far as weights are concerned is convenient and expressive, its adoption would not be attended with much expense or confusion, and the result would be a reduction of friction and misunderstanding both in internal and in international exchanges.

When we consider the difficulty of making a change in our system of measurements, we must all concede that there would be a period of some confusion and incidental expense during the transition period. Undoubtedly this burden would fall largely on machine shops. Perhaps in no other department of industry would it be of such serious moment, but even in the machine shop it is probable that the immediate necessary outlay would not be so great as it is sometimes urged. If all our tools, gauges, etc., had to be instantly discarded *en masse*, the proposition would be a very serious one. It is not believed, however, that any such procedure would be necessary. This subject was fully discussed by the recent committee of the Franklin Institute, and the several practical shopmen who were on that committee conceded that existing tools and gauges could be retained until they were gradually superseded, merely designating the nominal dimensions in the nearest convenient metric units. Messrs. Willans and Robinson, of England, who some years ago adopted the metric system of measurements in their workshops, write: "Existing tools and gauges can be retained, and can be used concurrently with those designed to the metric units, and is precisely what we have done for the last ten years without the least difficulty whatsoever, notwithstanding the fact that, owing to our special circumstances, tools and gauges to English units are still in use, and that without creating any confusion."

It is quite probable that any machinist who would seek to make the change would find that the cost of making new tools and gauges would be extended over such a prolonged period of time that the expense would not be seriously felt. So also with the tables of our technical literature. The works of French and

German engineers are at least as voluminous as ours, and we would need to do little more than reprint their tables.

We cannot claim all the advantages and none of the disadvantages for the metric system. Some practical advantages are inherent in our existing methods, and no one has expressed these with more persuasive force than our venerable and esteemed fellow-member, Dr. Coleman Sellers, in the various articles he has written on the subject. As he stands among the Nestors of our profession, his age and experience give his opinions great weight, and he has always been a tower of strength to the opponents of the system. Nevertheless, I might most respectfully observe that some of Mr. Sellers' arguments are not altogether convincing. For example, he refers to the practice of a German manufacturer of twist drills, etc., who, instead of making a uniform progression of diameters, varies alternately by 2 and 3 millimetres, in order to keep the even millimetre dimension. It is quite true that these dimensions would not be so readily borne in mind as when the advance is in exact arithmetical progression; but we might ask what valid reason is there why the dimensions in question cannot be advanced by fractions of a millimetre? For example, 10, 12½, 15, 17½, 20, etc. This is perfectly consistent, and is no more trouble to express than in the case of our common fractions.

Mr. Sellers also refers to the convenience of reducing finished shafting by $\frac{1}{16}$ inch diameter from the even rolled dimensions. This would sound better to the mill roller, if he was not reminded how he is frequently required to roll rounds, "full" in diameter. This fulness, which varies from $\frac{1}{32}$ to $\frac{1}{16}$ inch diameter, has long been a bugbear to the roller. Probably as practical units, 1 millimetre of reduction for small and 2 millimetres of reduction for medium diameters, would be about as close as we should attempt to work in turning finished rounds from actual rolled sizes. It is very true that the apparently small, but practical, affairs of life, and those which concern our workmen, should be given the most careful consideration in deciding this question.

Of course the predominant argument for the metric system is that it harmonizes with the universal notation of the world, and is the only method so far proposed that offers a promise of becoming accepted as an international system. This in itself is a most important consideration, and its consummation would justify some sacrifices if they would seem to be necessary, but in addition to the foregoing its advocates firmly believe that there are several practical advantages which would attend its adoption.

1. Simplicity of expression and enumeration. The common fraction is not required, and few qualifying symbols.

2. Facility for memorizing, rendering reference to tables rarely necessary.

3. Comparative ease of computation, owing to the constant decimal relation and the correlation established between the various weights and measures.

4. The ready measurement of drawings by the standard scale, and little liability of mistakes in the interpretation of quantities.

5. Convenient units of weight, both for large and for small quantities.

6. Units of length as convenient as our own, with the advantage of having in the millimetre a more convenient minimum unit for scales than we possess in our binary subdivisions of the inch.

As the matter now stands, we seem to be gradually working toward two standards, one used in scientific and semi-scientific work, and the other in the practical affairs of life. It might be suggested as a means of reaching a final decision that a commission be appointed of, say, a dozen men, three from the American Society of Mechanical Engineers, three from the American Society of Civil Engineers, three from the American Association for the Advancement of Science, and three from the New York Chamber of Commerce. Let these men be selected for their broad intelligence and freedom from partisan bias. Request this body to examine the subject in all its bearings and from every point of view, take ample time to reach their conclusion, and report the results.

A decision from such a body would influence the nation and its representative in the legislature, and would probably settle the question for the next generation.

In conclusion the writer desires to express his opposition to any compulsory legislation on the subject, even if the measure appears to be approved by a majority of the people.

It must win its way gradually by its own merit. When it becomes evident that the time is ripe for it, the national government can inaugurate the system in its own departments, whence it will soon spread through the manufactures and commerce of the nation.

Mr. F. A. Halsey.—Is it not queer logic that asserts that because we have one too many tons already that therefore we ought to introduce another—the metric ton. Will it be any easier to get rid of the long ton after the adoption of the metric system than now? Will the confusion that now exists between the two tons be any less among three? The long ton is the most familiar illustration we have of the persistence of an old unit, and its survival should teach the metric advocates the difficulty of getting rid of old units. Mr. Christie's easy assumption that the long ton would have disappeared if it had been made illegal is disproven by Mr. Henning's citation of the well known practice of calling 2,400, and even 2,700 pounds, a ton in the coal-mining regions, although that practice is subject to a heavy fine.

Mr. Christie's reference to the persistence of old units in European textile industries simply inverts the facts which show the survival of old units to be in the processes of manufacture by the highly trained technical men—not among the mass of the people. It is the mass of the people who use the metre in buying and selling their fabrics, and the technical men who use the aune, the moque and the denier.

I have endeavored to show, paragraph 70, that there is no parallel between a system of currency and weights and measures, and it is unnecessary to repeat the argument here.

I have explained that the experience of Germany in adopting the system furnishes no parallel for us. In Germany, as in France and Spain, the confusion owing to different units in different districts and even towns made a change of some sort imperative, and almost any change was bound to be for the better. Except for our two tons, we have no such confusion. The inch has but one value throughout this country.

The liability of confusion between feet and inches, to which Mr. Christie refers, is as nothing compared with the liability of confusion due to the varying places of the decimal point in the metric system, as well as to mistakes in placing it. I have explained that for any one purpose, the place of the decimal point must be fixed and understood, but this is not the case where different purposes are considered. Thus, for machine-shop use, the unit is the millimetre, and the decimal point is accordingly placed, or more usually understood as belonging after the figure for millimetres. For scientific work the point is placed after the centimetres, and for civil engineering work after the metres—

or in large surveys, I believe, after the kilometres. Again, while in shop work the unit of length is the millimetre, the unit of area is the square centimetre, with corresponding differences in the place of the point. Consider the invitation to error which these differences offer. *The unit intended must be distinguished in some way*, and there is a far greater inherent probability of error in the misunderstood or misplaced decimal point of the metric system than in the omission of the foot and inch marks by a draughtsman. Compare the simple English ticks to indicate inches with the fourteen movement m.m. necessary to indicate millimetres when distinction is required.

Mr. Christie has made a rational comparison of the number of figures required on drawings—which Mr. Henning has not—but where does the marked superiority come in? Taking his figures as they stand, they show a reduction in the number of figures required on mechanical drawings of between twelve and thirteen per cent. This is certainly whittling things to a fine point.

"A duodecimal base has many unquestionable advantages if it would be possible to obtain it without a revolution of a sweeping and destructive character." To that I cordially subscribe, but would add that the opposition to the metric system is based on the belief that *it* involves a revolution of sweeping and destructive character. I have endeavored to indicate how destructive it would be, and to this presentation Mr. Christie makes no effort to reply.

Mr. Christie's paragraph regarding the kilogramme and its usefulness in international exchanges would bear much elaboration, but this Society has little interest in other units than those of length.

To Mr. Christie's references to the experience of Willans & Robinson, I have referred in replying to Mr. Miller. In his reference to the cost of new small tools, Mr. Christie, like most of the metric advocates, looses sight of what I have endeavored to especially emphasize—the loss of standards as such. The chief cost of the change is not measured by the cost of new tools, but by the throwing away of standards, the value of which we will not know until we lose them. The value of shafting and pulley standards, for example, lies in the fact that by reason of them shafting and pulleys may be made in large quantities and therefore cheaply; that because their fitting is insured, they can be made in advance and sold from stock as needed, instead of being made to order at increased cost and delay; that pulleys can be changed about as needed, and if thrown out of use become again available for any shaft of their size, whenever wanted. Who would think of estimating the value of shafting standards to the country, by the value of the turning and boring tools and gauges in pulley and shafting factories? Nevertheless, that is exactly what Mr. Christie does in his references to the gradual change of shop tools. *Every reference to the cost of new tools tacitly assumes that present standards are to be abandoned.*

Mr. Christie's suggestion that we reprint French and German tables is especially unfortunate. A German table of the flow of water in pipes is applicable to German—that is, metric—sizes of pipe only, and similarly, a German table of the strength of beams is applicable to German—that is, metric—sizes only. These tables could not be used in connection with our sizes of pipes or beams. If we are to express volumes of water and loads on beams in metric units, and continue our existing standards of pipes and beams, we must have new tables. When our pipes and beams are changed to metric dimensions we shall need a third set of tables, and during the transition period we shall have repeated use for all three sets. This whole subject of technical literature leads to the most hopeless confusion.

Regarding Mr. Christie's experience in computing tables, I must repeat that I can conceive of no ordinary engineering calculation in which the slide rule, as compared with the usual method, leaves enough time remaining for the metric system to save to be of any moment, and if the system saved all that he thinks it does, I cannot conceive how the saving to the comparatively few who make calculations can justify a change on the part of the people at large, or how it can be a matter of any public moment.

Imagine a retail merchant to buy his goods in metres and kilograms, and to sell them in yards and pounds, or a wholesale merchant to sell to some customers by the metric and to others by the English system, or a manufacturer to make his goods by one system and to sell by the other—*as textile manufacturers are doing to-day throughout metric Europe.* One or all of these conditions must arise during the transition period, and all would give rise to endless transformations between the systems, all of which represent so much *added* labor. Refer to Mr. Dale's graphic picture of cost calculations in German textile mills, paragraph 9. The whole argument for the saving of time in calculations assumes the transition to be substantially complete. While before that time men may here and there be found who will experience a slight gain because the change in their occupations is complete, this will be many times offset by the endless transformations of others, so that *to the nation* there can be no gain until the change is practically complete. And what will it amount to then? What fraction of the time of the American people is devoted to calculating? There never was so small a mole hill magnified into such a mountain.

Mr. Christie has risen to the occasion which no other participant in this discussion has done, and has given us a list of the advantages which we are to gain by the adoption of the system. The whole lot, taken at its face value, is not worth as much as our pipe thread standards alone, and Mr. Christie, like the others, has failed to show how the adoption of the system can fail to involve *the destruction of all mechanical standards.*

The following extracts from a letter by Mr. A. M. Mattice, Chief Engineer of the Westinghouse Electric and Manufacturing Company, give experiences which relate to some of Mr. Christie's claimed points of superiority, and these come from sources which will command respect:

For a number of years I have had more or less occasion to have drawings made in the metric system. My experience has been that foreign draughtsmen who were originally brought up in the use of the metric system, and later come to this country and worked in theEnglish system, and have become as skilled in the use of the latter as in the use of the former, will work more rapidly on drawings in English measures than on those where the metric system is used. One of the reasons for this is the greater ease of using an easily sub-divided system like the English. Another reason is the greater ease of quickly picking out a dimension on scales in the English system.

The following incident is of interest in this connection: During a visit to Europe last summer, a party of us visited the Oerlikon Electrical Works in Switzerland. We were shown over their works by their chief draughtsman, Mr. Leon von Muralt, who was for several years with the Westinghouse Electric and Manufacturing Company, East Pittsburg, Pa., and is thoroughly acquainted with American practice. One of our party asked Mr. von Muralt the result of his experience in the English and metric systems. He replied without hesitation that "for drawings and shop use he considered the English system the more practical, but for calculations the metric system had the advantage." As calculations form a very small part of an industrial establishment, and as the greater part of commercial calculations are nowadays made by the slide rule or other calculating instruments, the advantage cited by Mr. von Muralt would not be appreciable.

I might mention another instance, as follows: The chief engineer of our French Company (Société Anonyme Westinghouse), Mr. W. E. Reed, was transferred from the parent company to the French company about three years ago. All the construction work of this company is necessarily done in the metric system. Mr. Reed, is, of course, thoroughly conversant with the metric system and is brought into contact with it hourly. Notwithstanding this, Mr. Reed makes all his calculations, except those in connection with transformers, in the English system, and simply translates his final results into metric measures. He does this for the reason that all of the formulæ and constants which he uses were learned in the English system, and it is easier to continue the use of them than to relearn them in the metric system. In the case of transformers, all the formulæ and constants which he uses have been worked out by him since he joined the French company, and for convenience he worked them out in the metric system. This case is an example of the difficulty of attempting to break loose from an existing system, where the new system does not offer sufficient advantages to induce one to make a change. If, after three-years' experience in the metric system, Mr. Reed had found that he could work more rapidly by calculating in the metric system, he would undoubtedly have done so.

Another example: Mr. Otto C. Reymann, mechanical engineer of the same company, is a German and received his technical education at Charlottenburg and Zurich, where, of course, the only system of measures used was the metric. Mr. Reymann spent about six years in practical work in this country, where he became accustomed to the use of the English system. He has now been with the French Westinghouse Company nearly five years, where he is daily brought into contact with the metric system. Notwithstanding this, he does all his thinking and calculating in the English system and translates his final results into the metric system.

Messrs. Reed and Reymann are both on a visit to this country at the present time, and I have to-day talked with them about this matter. I had previously heard that Mr. Reed still worked in the English system and he has confirmed that understanding. It was not until to-day that I knew that Mr. Reymann was also using the English system. In his case it would be natural to suppose that, having been brought up in the use of the metric system, when he went back to Europe he would have gone back to the use of that system if it possessed the great advantages which are claimed for it by its advocates.

In paragraph 71 we have the unfavorable experiences of Mr. Linnard, and in paragraph 72 that of Mr. Hess. The great savings of time in calculation by the metric system are imaginary.

As regards the convenience of English and metric draughtsmen's scales, the experience of Mr. Hess is also distinctly unfavorable to the metric scales. Mr. Hess says:

From the draughtsman's point of view, the binary system is also decidedly more convenient. . . . Actual use will convince anyone of the truth of this, as it has me, who confesses to having been very sceptical as to there being a practically noticeable difference in convenience of quarter against fifth, and eighth as against tenth, scales.

The experience of William Sellers & Co. is the same as that of Mr. Hess (see *Transactions*, vol. i., page 38).

Finally, Mr. Christie is not in favor of compulsory legislation, but, like all the others, he fails to point out how a law which requires the use of the system in a transaction can fail to be compulsory on both parties to the transaction. Further, such progress as has been made elsewhere has been due to compulsory laws. With the record of that experience before him, how long does Mr. Christie think the transition period will last with us and without compulsion?

Mr. Fred. J. Miller.—In commenting upon this paper I do not propose to present the argument for the metric system, but simply to call attention to the fact that there is such an argument. So far as the records of this Society go, I believe they do not show that there is any argument in favor of the metric system. Every paper that has been presented upon the subject has been against it, and the only committee that has ever been appointed by the Society to do anything in connection with the subject of the metric system is composed exclusively of strong opponents of the metric system—men of great ability, it is true, but making up a committee which, by its constitution, is utterly unable, and, in fact, does not intend to, give the subject impartial consideration. Of course this Society is not organized to advance or to oppose certain proposed reforms, but rather to get at and present the facts regarding any question that may come before it, and in order to do that it must obviously consider what may be said on both sides. This, it seems to me, has not been done; and what I shall have to say will, therefore, be for the purpose of showing that at least there is an argument on the other side which we ought to consider before putting ourselves upon record.

Mr. Halsey opens his paper with a citation of the fact that scientific and trade societies are calling for the passage of the bill now before Congress, looking to the partial adoption of the metric system in the various departments of the government, and he names several men who are well known engineers, members of this Society as well as others, who favor the bill and the adoption of the system. Now, anyone who will take the trouble to look up the records will find that in every case where such societies as the Western Society of Engineers, the Franklin Institute, the Engineers' Club of Philadelphia, etc., have taken action upon this question, they have done so only after a special effort to bring out all the arguments possible on both sides, and to carefully consider those arguments. Does it not seem the part of wisdom for this Society to pursue the same course—the truly scientific course—before attempting to decide? Must we conclude, as the author of the paper would evidently have us conclude, that all these well-known men and societies are simply blind, and that only he and others who oppose the metric system can see?

History is full of examples in which the wisest of men have become worshippers of a fetish, and have firmly believed that anyone who presumed to say a word against this fetish ought to be ignored, imprisoned, or boiled in oil, depending upon how far back into history we go for our examples. Let us not be worshippers of any fetish, but rather let us follow the example of those other societies cited by Mr. Halsey, and many others not cited by him—conduct a careful and impartial investigation, then decide, by a full vote of the Society, if it is considered desirable that the Society should place itself on record in the matter. It seems to me the height of folly to conclude, without examination, that such men and societies as are cited in the paper, and many others that might be mentioned, have come to conclusions favorable to the metric system, without having any reasons therefor worthy of consideration.

I pass over the fact that gems are weighed by the carat in metric-using countries, and that expressions both for and against the metric system may be extracted from the famous report of John Quincy Adams, as being comparatively unimportant, and will confine myself to the consideration of what people of to-day are doing and thinking about this question—people who, for the most part, are directly connected with the business and art of producing machinery.

This cuts out all that Mr. Halsey has to say about the great confusion that exists in the textile industries of Europe, which confusion results apparently from the fact that they *do not use the metric system.* All of what is said in the paper on that point seems to show simply that there has been no compulsion with regard to the use of the metric system in the textile industries of Europe, and that they are therefore using the numerous standards that were in use before the introduction of the metric system. To say that this confusion is caused by the metric system is to remind one of what the boy said in his essay upon salt. He said, "Salt is what spoils your potatoes when you don't put any on." In like manner the metric system produces great confusion in the textile industries of Europe when it is not used. Mr. Halsey's plan for remedying the present deplorable condition of affairs there would seem to be, to give up trying to do anything, and to go on using the 21 different ells, the "picks," "cuts," "skeins," etc.

We, however, are more interested in this matter as it applies to the construction of machinery, and in this connection I beg to say that during the past 15 years we have received in the office of the *American Machinist* many blue prints made in the draughting-rooms of European machine shops. Not one of these blue prints has been based upon an ell of any kind or value, nor upon an inch of any kind or value. All of them have been figured in millimetres, and, so far as I recall, not one of them has had upon it a decimal or other form of fraction. I have spent considerable time in inspecting and studying European machine shops, and never encountered any other than the metric system in any of them. This is not to be despised as negative testimony, but, on the contrary, proves, I think, that there is a practically general, or almost exclusive, use of the metric system in European machine shops. And I think the conclusion is a fair one that this system has come into use in European machine shops because it has been found to be a good system for the purpose; because it has been found advantageous to use it rather than any other; for, as Mr. Halsey has himself shown, there is no effective compulsion about it, and the machinery builders of Europe could undoubtedly have gone on using their old mixture of standards just as the textile men have done, had they chosen to do so; or, in other words, if they had not been open-minded enough to perceive that the new system offered advantages that made it worth while to adopt it.

Were I a metric system advocate I might reply to much which attempts to show that if this bill passes we shall have to abandon all our present standards for parts such as enter into the construction of machinery. I most decidedly do not believe any such thing; but I pass it over to be considered by others, while I confine myself to the task of attempting to show that it is at least worth while for this Society to make a thorough investigation of the whole matter. I cannot refrain from noticing, however, in passing, at paragraph 65, the reference to the tank of water illustration, which, of course, is used by metric advocates only as typical and not because they think that engineers spend most of their time computing the weight of tanks of water. But since the author of the paper brings this up, says it is contemptible, and that not 10 per cent. of the members of the Society ever have to make such calculations, I will ask what percentage of the members ever have to count "picks" or "hanks" or "cuts," or compute yarns, using these standards together with some 21 different ells in finding out how much yarn will be required for a yard or a metre or an ell of cloth. If one illustration is contemptible, perhaps the other is at least equally so. My own opinion is that neither of them have much bearing upon the question of whether it is or is not best that the bill now before Congress should pass into law, or whether or not it would be advantageous to introduce the metric system into American machine shops.

It is not very important so far as it relates to the question under discussion, but should be noted, perhaps, that, in the calculation mentioned in paragraph 67 of the paper, only three partial products are required in squaring 2,438. When in multiplying you have a partial product obtained by multiplying the multiplicand by a number which is a factor of any other figure or group of figures in the multiplier, it is necessary only to multiply such partial product by the other factor. Applying this rule to the case in point, we find that when we have the first two partial products we can get the product of 2,438 by 24 simply by multiplying the first partial product by 3 or the second one by 8, and this reduces the labor and the number of separate mental operations by 25 per cent.

With regard to the problem referred to in the letter from Mr. Hess, quoted at paragraph 72 of Mr. Halsey's paper, this aroused my curiosity a little, and I wrote to Mr. Hess for particulars, and under date of October 28th he replies, stating that the problem consisted of converting horse-power consumed in removing in the lathe a given quantity of iron per second, expressed in cubic centimetres, into horse-power per x-kilos per hour. The result as stated was that some of the computers got the decimal point misplaced by as many as six places. This is somewhat curious, and it seems to me morally certain that if those computers had been accustomed even a little bit to computations of that nature, or if they had possessed only a little knowledge of the rate at which iron is removed in the lathe, and the horse-power consumed in removing it, they would have been able to make the computation all the way through, disregarding the decimal point entirely, and could then have placed it correctly in the answer simply by inspection and guided by their experience in such matters. In other words, it would have been impossible for them to have failed to notice an error which made the result either ten times too large or ten times too small, as would have been caused by misplacing the point one place. Does it not seem likely that a computer so unfamiliar with the subject as not to detect an error one hundred thousand times too large or one hundred thousand times too small, would have been about as likely, in making such calculations in our system, to have mistaken cubic inches for cubic feet, linear inches for linear feet, or even pounds for tons? Such mistakes are not unknown in our system of measuring and weighing, and such a mistake would produce a far less noticeable error than to misplace a decimal point six places.

The author's reference to the slide rule in an argument against a decimal system is, it seems to me, unfortunate for him. Slide rules are decimal; made so, I believe, because that is by far the more convenient, and in handling common fractions by their aid, it is necessary first to convert the common fraction, into decimal fractions, and then at the finish convert them back again, if the computer thinks he must have the answer in common fractions. And there are men who, for some inscrutable reason, seem to think that $\frac{1132}{1728}$ is more intelligible or "more easily grasped" than its décimal equivalent, which, by the slide rule, I make to be 0.655.

In paragraph 93 of the paper the author says that we hear of no call from civil engineers for a new set of units for land measure, and he gives as a reason for this the poetical expression so often quoted in his paper, "measures of length are tied irrevocably to the past." Let me give what is, perhaps, a more definite and practical reason. All land measuring is done by a strictly decimal system. A surveyor, during the performance of his work, has absolutely nothing to do with yards, rods or acres. He measures entirely with a chain the length of which was chosen by its inventor, Gunter, to adapt it to decimal computations of areas, and this chain is subdivided into 100 links, the object of this invention being to do the very thing that Mr. Halsey declares is so undesirable to be done; *i.e.*, to make all calculations of land areas decimal until the surveyor comes to the final one, which is made to convert into acres. And even here the fractions of an acre are usually, or at least often, expressed in deeds and other papers in hundredths or thousandths of an acre instead of in square rods, yards, feet and fractions.

After quoting the opinion of Mr. Linnard, a naval architect of the Navy Department in favor of the present system, Mr. Halsey says, in paragraph 71 of the paper, "Such testimony cannot be ignored. It is worth more than all the essays and *à priori* arguments that can be written from now until doomsday." I endorse that sentiment, and will now present some other testimony of the same character; *i.e.*, the testimony of men who have given the matter careful study, and most of whom have had experience in the use of the metric system in the construction of machinery. Most of us know of the firm of Willans & Robinson, of Rugby, England. Many of us have been in their establishment, and know that this firm is not likely to be found pursuing will-o'-the-wisps or, in fact, doing anything that is not strictly practical. No metric law has been passed in England, and no one ever tried to compel this firm to adopt the metric system. Yet they have virtually adopted it, voluntarily, and simply because they have found it advantageous to do so, and to continue in its use. Their earlier engines were designed to the inch system, and tools and fixtures were made for them. They still continue to build those engines to that system, but along with them and in the same shop they build other, later designed engines, to the metric system, and their testimony is unqualifiedly in favor of the latter system. Captain Sankey, who is a director of the company named, read a paper before the Institute of Civil Engineers in 1897, in which he stated in effect that with the two systems in use side by side in the same shop, and doing similar work, the metric system was much the better liked, both for the shop and for the draughting-room, and in his paper he went into details and gave the reasons for the preference at length.

Testifying before a parliamentary committee on this point, Captain Sankey was asked:

Q. Have you found any difficulty with your workmen in this respect?

A. Absolutely none.

Q. Do they adopt it and see the advantages of the system?

A. I should say so. In fact, in connection with my coming here this afternoon, I asked four or five of our men privately (not through the works manager) what they thought of it, and there was not a dissentient voice among them. They all agreed at once that the millimetres were very much easier to work to than the English measurements.

Q. I understand you found your men had not the slightest difficulty in adapting themselves almost immediately to the new system?

A. Not after the first few days. I asked that very question of the head of our tool-room, and he said it was a little awkward for a time. I said, "About how long?" and he said, "Two days."

The *American Machinist* has not asked the views on this question of men who merely think that the one or the other system is the better for the machine shop, but has invited statements of experience by those who, in machine shops, have had experience with both systems, and may therefore be assumed to be in a position to speak from actual knowledge. At page 1357 of the current volume, Ernest R. Briggs, who is connected with the Willans & Robinson firm at Rugby, has a communication from which I quote a few paragraphs:

Trade is no longer local; it is no longer national, but it is international; and surely none recognize this better than American machine tool builders. With an international trade it becomes imperative to have an international system of weights and measures. As the needs of trade caused manufacturers to fix standards half a century ago, first for their local, and then their national, trade, so now the same need is causing the movement toward international standards.

. . . .

New jigs, gauges, dies, etc., are required for the new engines, irrespective of the standard of measurement, and these are, of course, made in millimetres. There is no difficulty with the workman; he has a scale with millimetres *only* on it, and as the drawings are figured only in millimetres, he must use it, and experience shows that in half an hour he has learned all he need learn.

If the draughtsman has done his work well, he has figured all work required to be worked to with small standard gauges in even millimetres, and a set of such gauges is obtained and placed in the tool-room or elsewhere, with the existing standard English gauges.

Screw threads are for the present kept the same; even continental firms have not wholly adopted the metric screw threads; large numbers use the Whitworth. If we are content to use wire and plate gauges that cannot be expressed under seven places of decimals, why stick at using Whitworth or Sellers threads on metric work? It is worth while noting that electrical engineers largely use the British Association standard threads for small work; and they have no difficulty in using these screws—based on the millimetre—for work based on the inch measurement.

Experience has proved that it is possible to use the metric system side by side with the English system, and that there is no difficulty in even making parts of one standard fit to parts of the other standard, and so gradually, bit by bit, the old series can be withdrawn and none but the metric remain in use. The actual time taken in this transfer period cannot, of course, be fixed; it depends upon purely local conditions; but the sooner the better.

There will be little difficulties cropping up from time to time during the process of introduction, but these will grow less and less as the work progresses, and manufacturers making complete articles, such as engines, machine tools, etc., need have no fear but what the result will be successful, provided the matter is taken up whole-heartedly.

The entire article by Mr. Briggs is well worth reading, especially when we remember that it is written by a man who is in the engineering department of a works actually using the two systems, and in this connection I may mention the fact that, when in Chicago some years ago, I found the M. C. Bullock Company making the Willans engines to the same drawings as made by the Rugby concern. I asked the superintendent of the works if he had any special difficulty in handling the work to the metric system there in Chicago, and he said they had none whatever. At the same time in the same shop they were building mining machinery to the inch system of measurement.

Lord Kelvin, whom most of us will be willing to acknowledge ought to know something of measuring, of weighing, of computing, and of which is the best system for these, has taken the trouble to testify most emphatically in favor of the metric system before our own Congressional Committee; and before a committee of the English Parliament he said, in speaking of this question:

I believe that the difficulty of making the change has been enormously exaggerated. I believe that in a fortnight people would become so accustomed to the perfect simplicity and easy working under the metrical system that they will feel that instead of its being a labor to pass from one system to the other, it will be less than no labor; that is to say, it would be a very great saving of labor after the first day or two of beginning to use the metrical system.

Mr. Halsey says in his paper that our foreign customers do not care a picayune whether we adopt the system or not. I believe that is substantially true; but let me quote the opinion of one foreigner, bearing upon this matter.

A committee of the American Railway Association addressed a communication to Mr. L. Weissenbruch, secretary-general of the International Railway Congress and chief engineer of the Belgian State Railways, regarding the use of the metric system in railway work. Mr. Weissenbruch, after describing some of their methods and customs, commends the paper of Captain Sankey, which has already been referred to, and says that this favorable record of actual experience is better than all theoretical discussion of the matter. Finally, he says:

As secretary-general of the Railway Congress and from scientific interest, I am happy to understand that the metric system has some chance of being adopted in the United States; but as a citizen of Belgium I may perhaps regret it, because it would greatly aid the Americans to compete with Belgian industries in countries to which they export.

Those of us who know anything of the work of Arthur Bollinckx, of Brussels, Belgium, will agree that he is a very practical man and a very successful builder of Corliss engines. In the *American Machinist*, vol. xxii., page 137, Mr. Bollinckx, in replying to an article by Professor Sweet, says:

The economy of time realized in using the metric system will certainly pay for the few annoyances caused by the changes you will have to make in plans.

At Leeds, England, is the large engineering workshop of Greenwood & Batley, which does, and for many years has done, a very large business in the export of various machines and tools to Continental Europe. At the Glasgow Engineering Congress of 1901, Mr. Arthur Greenwood, of the firm mentioned, read a paper strongly advocating the adoption of the metric system by Great Britain, basing his reasons for such advocacy solely upon commercial and other strictly practical reasons. He expressed himself as most decidedly of the opinion that it would be a great advantage in his firm's foreign business, and gave instances from actual experience. He testified also that in the tool-room of the works at Leeds the metric caliper gauge had been in use for twenty-five years, and was as familiar as the inch gauge, very little difficulty being experienced by or with the men in using it. In a Russian engineering works in which he is interested, he said both systems are in use, and that little difficulty is experienced in their joint use. At the new works just then completed at Leeds for the manufacture of the De Laval steam turbine, the metric standard had been adopted in combination with the Whitworth threads. This seems to have been done entirely as a matter of free choice, and for no other reason than that it was believed to be commercially and mechanically advantageous.

Most of us know of Sir Benjamin Baker, the builder of the great Forth bridge in Scotland. He says, in speaking of this subject:

I am equally familiar with both systems, in consequence of having carried out works abroad, and when I return to this country [England] from such work and experience with the metric system, I think there is nothing more foolish in this world than our weights and measures.

Mr. E. W. Mix served an apprenticeship with, and for some years afterwards was connected with, the Thomson-Houston Company, at Lynn, Massachusetts, and was then sent to France in their interest. He is now the chief engineer of the establishment in France, which manufactures for the French Thomson-Houston Company (the *Société des Etabs, Postel-Vinay*). As such he has, of course, had unusual opportunities for testing the relative merits of the two systems in the construction of machinery. A gentleman who is prominently connected with the Pratt & Whitney Co., of Hartford, Connecticut, suggested that I write to Mr. Mix for an expression of opinion, possibly thinking that Mr. Mix's opinion would be adverse to the metric system. In reply to my inquiry, Mr. Mix excused himself from writing at length about it, on account of recent illness and pressure of work, but said he would be glad to go into it at length if he could, for, to use his words, "This is an interesting subject, and I am convinced that the metric system presents enormous advantages over the system in use in the United States."

A few years ago several men who had been trained exclusively in American machinery-building establishments went over to Berlin to take various positions of responsibility with the firm of Ludwig Loewe & Co. One of these men is Mr. C. L. Libby, member of this Society, a well-known designer of machine tools, and superintendent of the machine-tool department of the firm mentioned. Mr. Libby is now located in Madison, Wisconsin, and writing from that place in August last, after having closed his experience of about three years with the metric system and gone back, perforce, to the inch system, he says:

As to the relative merits of the metric and English systems of measurement after having used the metric system for four years in Germany, I must say that I think it far superior for both machine shop and drawing-room.

The inch is such a large unit that it must be subdivided in fractional parts, and when the dimensions of a piece are given on a drawing in eighths, sixteenths, thirty-seconds and sixty-fourths, as is often the case, it becomes difficult for the average mechanic to add them together correctly. On the other hand, the millimetre is so small a unit that it is seldom necessary to subdivide it into fractional parts. If it becomes necessary to subdivide the millimetre it is always given in decimals, and one can multiply, divide or find the log without first reducing to its equivalent decimal, as one does with the fractional parts of an inch.

I think a drawing figured in millimetres is more convenient and looks much better than when the inch and fractions are used, and I am of the opinion that there is less liability to error on the part of the draughtsman.

Of course it takes some time to be able to think in millimetres and get a clear idea of just how much a given measure in millimetres is, without first translating to inches. But after a little, and almost unconsciously, one begins to think in millimetres without referring to the inch.

Associated with Mr. Libby in Berlin was Mr. H. B. Bartlett, a well-known and expert tool-maker, designer and mechanician, who was for some years with the Linotype Company here, and afterwards with the Pratt & Whitney Co. in their small-tool department. In Berlin Mr. Bartlett was superintendent of the small-tool and gauge-making department. Being asked for an expression of opinion upon this matter, Mr. Bartlett, writing under date of October 18th from Berlin, says:

I am strongly in favor of the metric system being adopted in our country, but discussion over the pros and cons can last longer than that on the resumption of specie payment, and I think Horace Greely's advice on the latter would apply very well in the present case. I don't believe in ridicule or even humor as an argument; but when that becomes necessary, I think the opponents of the English standard have the best of it on their side.

It seems to me that the Irishman who, given a two-foot rule with which to measure a piece of timber, and reported it being "as long as that stick ye gi' me, two bricks and the width o' me hand, barrin' me thumb," was getting back pretty close to the origin of our present standard, or laying an equally good foundation for a new one.

My five-years' experience with the metric system here has increased my liking for it, which was pretty well fixed nearly twenty years ago, after about two-years' experience as a tool-maker in a New England factory where it was the exclusive standard. This factory afterward went back to the inch, but with decimal subdivisions—a sort of involuntary compliment to the former system. I, however, prefer the millimetre as a unit to the inch in shop measurements in the construction of machinery. There is no special difficulty in learning it, and one soon becomes accustomed to thinking in millimetres without translating into inches in order to form an idea of their value. My experience has been only with the millimetre as a base unit, but I have talked with many American mechanics here with experience on bridge and shipbuilding work, who are unanimous in favor of the metric standard. One especially, an electrical engineer, said, "I don't see how we ever got along without it; and my only regret at having to return to the States is the English standard of measurement that I shall have to take up again.

I don't think the question as to whether the workman prefers to work to the inch or not is of any importance. In the average machine shop, all he has to

know is how to count and what, and that will most likely be millimetres, and not centimetres and decimetres. The draughtsman is the man who would have the most difficulties in learning it, and to the average one it would be recreation of a pleasant kind; but I think the majority could drop one and take up the other at once with no trouble whatever.

Albert E. Guy was born in France, was educated and worked there as a mechanical engineer. Now, and for some years, he has been in this country, and is at present the chief engineer of the Gas Engine and Power Company at Morris Heights, New York City. First educated in the use of the metric system, he now uses our inch system in the designing of machinery and the making of drawings. Such a man ought to be competent to express an opinion as to the relative merits of the two systems. I asked him to express such an opinion, without knowing what that opinion might be. If there were any inherent superiority in the inch system, it might be supposed that Mr. Guy would by this time have discovered it, but he has been unable to discover anything of the kind; but, on the contrary, in an article published at page 97 of the *American Machinist*, current volume, he declares his conviction that the metric system is much superior, and explains at length why he considers it to be so. He gives instances in engineering work wherein the metric system saves much labor as compared with the inch system, and, speaking from an intimate knowledge of France and the customs there, says that the exceptions to the use of the metric system there are unimportant, and that even in towns remote from the great centres of population no other system is known than the metric.

Mr. Francis E. Drake, as most of us know, was born and has been educated in the United States. Accustomed to the inch system, so far as I know he had no experience in the metric system until he went to Paris previous to the opening of the Exposition of 1900, in charge of the American machinery exhibits. Certainly he was not prejudiced in favor of the metric system, but his experience in France, in installing machinery in the Paris Exposition, as a member of one the Juries of Awards in the machinery class, and afterward in reorganizing one of the most important electrical industrial establishments in Germany, has convinced him of the superiority of the metric system from a business standpoint, Mr. Drake professing to be a business man rather than an engineer. It happened that the electrical establishment in Berlin which he was called upon to reorganize was building electrical machinery to both the English and the metric system. This was done in the same shop, by the same draughtsmen and the same workmen. He states that the draughtsmen and workmen, whether trained originally in one system or the other, almost uniformly preferred the metric system, and that the work did not cost more with one system than the other, the fact being that the men received the same piece-work price for a given job, whether it were made to the metric or to the English system, and the total cost of the work, as shown by careful records, was the same, no matter which system was used. As a result of Mr. Drake's experience in conducting business with men located in all parts of Europe, and of his devotion to the interests of American manufacturers, he declares himself as being strongly in favor of the metric system for purely commercial reasons, and closes his article in the following language:

Looking at the financial results, can we always afford to force upon a man a sack coat when he wants a frock?

I respectfully submit that such testimony is not to be despised, and that it is not safe for us to disregard it any more than it is safe for us to disregard the claims made for the turbine engine, or a new turret lathe, or a new system of paying wages to shop men. American manufacturers do not want to be protected from new things because they are new, but they want to be put in possession of all the facts and arguments on both sides, and they want to adopt and use those things which will place them on the most advantageous footing in their competition with the world.

I yield to no one in point of interest in American machine shops and their continued prosperity. I desire that as sincerely, I believe, as does the author of the paper, or any other opponent of the metric system. In fact, I do not stand here as a thick and thin advocate of the metric system. I frankly confess that there are strong arguments against it, especially to its enforced introduction into our American machine shops; but at the same time it seems to me that the evidence I have presented, and much more that might be presented, indicates that at least there must be some very strong arguments in favor of the system, and that in actual use in the construction of machinery it must possess some important advantages which make it commend itself so strongly to men whose earlier education and experience has been such as to tend to prejudice them against it—advantages which, if it really does possess them, we as a manufacturing nation cannot afford to neglect.

As to what Mr. Halsey says about the value of standards of length, we all, of course, agree with that, and probably most of us appreciate it as well as any one can; but I do not believe that the bill now before Congress, nor any bill that can possibly be formulated or enacted, can possibly cause our American machine shops to throw away their costly special fixtures, gauges, etc. My belief is that a full compliance with the pending law will be secured when a machine builder simply goes on manufacturing his machines as he does now, and with precisely the same taps, dies, jig, reamers, and all other tools and fixtures; but when a department of the Government wants a machine he will probably be required to state all the dimensions given in the specifications in millimetres. I can see no great hardship in that. A clerk or a draughtsman with a conversion table and a pencil can do it for any machine in a very short time, marking the metric dimensions upon a blue print if required; and whatever added cost of the machine may be caused by this will be imposed upon all bidders alike, and will inevitably be shown in the bids. In other words, if the machines cost materially more —which I cannot see that they will—the Government will have to pay the added cost. And in this connection it should be remembered that the fact that metric and inch dimensions are not reducible to precise equivalents is of no importance, because dimensions of machines as given in specifications are not expected to be exact, but only approximate. A man specifies that the main bearing of his lathe or milling machine is 3½ inches diameter, and then he grinds it to some other diameter, usually a little smaller to allow for lubrication; the allowance varying with different builders and with different circumstances. In other words, the figures of dimensions given in specifications of machinery are understood to be approximate except in comparatively rare cases, in which rare cases the string of decimal figures can be carried out to give any degree of precision that a Government engineer may fancy to be necessary, and he, with his gauges, will never discover the difference, nor be able to do so.

I do not believe that any machine builder will throw away any tools or fixtures on account of this proposed law. He will wear them out building machines, some of which machines may go into the Government shops just as they do now. But when he comes to designing an entirely new machine, he will, if he feels inclined to do so, design it to the metric system; and I have presented testimony from those whose experience ought to enable them to know all about it, to the effect that the draughtsmen and the men in the shop will not be bothered or perplexed by that, but, on the contrary, will care little about it, or will be pleased with the change and find it advantageous in their work.

The Society's committee has expressed its opinion that the pending bill is intended to compel us all to use nothing else but metric measurements and weights. The author of the paper before us takes, I believe, the same position. Now, I would much rather take the opinion of any one of these gentlemen upon an engineering or mechanical question than to take the opinion of the Attorney-General of the United States upon such a matter, and by the same token I hope I will be pardoned if I express very much more confidence in the opinion of the Attorney-General upon a matter of law or the interpretation of law than I could have in the opinion of any member of the committee or the author of the paper. Attorney-General Knox has been for many years receiving high fees from very large industrial and other corporations for his opinions upon matters of law. It has been very important to him and to others that he should be able to understand the meaning of a law or of a proposed law. He has expressed an opinion upon this law, from which I quote as follows:

The purpose and effect of each of these bills is to establish the metric system as the legal standard of weights and measures in the United States, and to require all government departments to use only that system, except in completing the survey of the public lands. This comes far short of attempting to compel the people to use only that system, or prohibiting to them the use of any other, or making invalid contracts expressed in other terms. Indeed, as each bill prohibits to the departments the use of any other system, by a familiar rule of construction this will be taken as the only prohibition intended, and it will end there.

But a negative answer to your question does not depend upon a mere rule of interpretation, but is based upon much broader grounds. The result referred to—the making contracts illegal for this cause—can be accomplished, if at all, only by clear provision to that effect, and there is nothing of that kind in either of these bills, which, as to this, merely declares that a system different from that now in common use shall be the legal standard. This by no means declares that no other system shall be legal or be used. It is both elementary and fundamental that a thing which is legal and innocent in itself is not made otherwise by making something else, even its opposite, legal, unless, indeed, there be such incompatibility that they cannot coexist. Our present system has been always and is just *as* much the legal standard of weights and measures as if it had been so declared by statutes in the very language of these bills; and yet there has never been a time when a contract expressed as to weight or measure in the terms of the metric or other system would not have been just as valid as if expressed in the terms in common use. And so it would be under either of these bills—just as the parties may express themselves in any language they choose, so they may designate weight and measure in any language or by any system that expresses their meaning.

The terms, figures and characters in common and almost universal use in our system of weights and measures are just as much parts of the English language as is any other portion of that language, and to forbid to the people their use would require as clear an expression of the legislative will as it would to forbid the use of that language in other matters, even if that would be effective. It may well be doubted if it would be within the competency of Congress to forbid to the people, for this or for any other legitimate purpose, the use of this or any other portion of the language in which our Constitution, our laws and our literature are written and in which we orally express our thoughts and feelings. But however this may be, it is certain that nothing of this kind is done by the adoption as the legal standard of a system of weights and measures different from that now in vogue, and which, so far as the people are concerned, merely adopts the metric system as the legal standard and launches it under government auspices and recommendation without any attempt to compel its use by the public at large. And specifically replying to your general question, I am of opinion that neither of the bills referred to, if enacted into law, would at all affect the legality or validity of any contract thereafter made because expressing its stipulations as to weight or measure in terms other than those of the metric system.

Respectfully,

(Signed) T. C. Knox,
Attorney-General.

The Society has a committee which was appointed for the avowed purpose of gathering material with which to oppose the metric system. I suggest that it would be better to have a committee appointed for the purpose of investigating the subject on both sides in a truly scientific way, and reporting.

Mr. F. A. Halsey.—With the single exception of the Franklin Institute, I know of no case in which a vote on this subject by any society has been preceded by an inquiry worthy of the name, and of the Franklin Institute committee but a small minority are mechanical men. I shall have more respect for the votes of civil engineering societies when they include their own units among those which they vote should be changed.

"The confusion in the textile industries of Europe results from the fact that they do not use the metric system." I have shown that this change is a matter of such difficulty that it is not yet complete even in France, and that the French people are still in the confusion of the transition period. Mr. Miller thinks he can dismiss this by his potatoes and salt story, but few will agree with him. It is difficult to believe that this was expected to be taken seriously, as it is impossible to believe that the reference to the slide rule was expected to be so taken. The slide rule must be divided in accordance with our system of notation. So long as that system is based on 10, it is impossible for general purposes to make, or to use it if made, with a slide rule divided other than decimally. Were our notation based on 9, 11 or 13, the slide rule would of necessity be divided accordingly, and it would furnish just as good and just as worthless an illustration of the merits of those numbers as bases of notation that it now furnishes of 10.

The persistence of old units "seems to show simply that there has been no compulsion." This is typical metric logic. Mr. Miller might as well say that because crime exists, therefore there are no laws against crime. Of course the facts are that the compulsory metric laws exist, but that they are to a large degree ineffective, because the people will not have the system.

Mr. Miller passes over the destruction of mechanical standards "to be considered by others"; but others, apparently, have passed the subject over to him, for no one has discussed it. This is the crux of the whole matter. Until someone has answered my argument that the retirement of the inch involves the abandonment of all standards based on the inch, this paper is unanswered and untouched. Mr. Miller's "I do not believe any such thing," does not count. He, of all men, is the one from whom we have a right to expect a defense of this position, but, like all the rest, he fails to give it.

The tank of water illustration is "typical." It is nothing of the kind. The fact that the metric unit of weight is that of a unit of volume of water introduces simplicity into calculations relating to the volume and weight of water, that exists with no other substance. Mr. Miller thinks that calculating the weight of a tank of water and the cost calculations of the textile industry (measured by its number of employees the largest single industry we have) equally contemptible, but few, I think, will agree with him.

What right has Mr. Miller to throw doubts on the ability of the draughtsmen employed by Mr. Hess? He thinks them incompetent because he would like to have them incompetent. *Mr. Hess knows the men.*

"Land measures are not to be changed because they are divided decimally," which is a tacit admission that dividing our other units decimally would place them upon an equality with the metric units. As will be seen presently, this is exactly the conclusion to which, after ten-years' experience, the superintendent of the Willans & Robinson works has come.

There is nothing in this paper which opposes the use of decimals for the purposes to which they are adapted. The metric advocates labor under the curious hallucination that their system has acquired an exclusive right to their use, and that one who uses decimals in any way whatever confesses the superiority of the metric system. Decimals were invented long before the origin of the metric system, and may be used with perfect consistency in connection with English units. The basic idea of the metric system is that no other divisions shall be used, and the metric advocates are therefore logically estopped from using other divisions.

Referring to Mr. Miller's letters from those who have used the system and "like" it, they are chiefly remarkable for their failure to show why they like it—that is, for failure to show what is to be gained by the change. Mr. Libby prefers the millimetre to the inch because of its size; Mr. Bollinckx refers to a saving of time (presumably in calculation); and Mr. Miller says that some of his authorities, Mr. Greenwood, for example, have given reasons for their preference elsewhere, but not in anything quoted here. Is it not remarkable how the metric advocates, when pressed for the reasons for the faith that is in them, fail to give anything tangible? Even Mr. Miller recognizes this deficiency in saying, "It seems to me that the evidence I have presented, and much more that might be presented, indicates that at least there must be some very strong arguments in favor of the system." If I were to appeal to a lot of people who preferred the English system, without saying why, and concluded by saying, "It seems to me there *must* be some very strong arguments, etc.," Mr. Miller would be the last one to accept such testimony as having any value, and so I must decline to place any value upon it. It seems to me time that the reasons were forthcoming.

The prominent point of these letters relates to the fact that the workmen readily learn the use of the system. Nowhere in this paper is there a word to indicate that I doubt this, and hence all these citations answer nothing. In point of fact, I do not doubt it. I have evidence to show that metric mechanical judgment regarding sizes of parts from the designer's standpoint is a matter of slow growth; but given the metric scales and tools I have no doubt that the workmen in the shop would soon use them with perfect facility. Those who imagine this to be the chief difficulty show how little they comprehend the subject.

So far as the experiences of Willans & Robinson and of Greenwood & Batley go, it is to be noted that in neither case is the change complete nor the end in sight, and the experience of neither shows how national standards are to be preserved. In the case of the former firm, with a new industry having very little history behind it when the change was entered upon, and with a declared policy of change, ten years of effort still finds the old system in large use. What light does this shed upon the length of time required for a general change by this country, with the indifference of the public and the direct resistance of many interests? What light does it shed on the chipper assurance of the metric advocates at the Washington hearings that this country could make the change in from three to five years? These citations simply show the fatal ease with which the change may be begun.

Regarding Mr. Guy's experience, it is sufficient to say that he left France when eighteen years of age. Not many of us have an intimate knowledge of the internal administration of many lines of industry at that age, and I must doubt if Mr. Guy's experience was materially different from others in that respect. The evidence regarding the persistence of old units in France is overwhelming.

So far as these favorable opinions go, we have in this paper the unfavorable opinions of Mr. Hess, Mr. Benét and Mr. Ball, whose opportunities for forming conclusions are as good as those of Mr. Miller's correspondents. Note that Mr. Benét is a Frenchman; and the following is from another native of France —Mr. H. L. Des Anges, superintendent of the floating equipment of the Long Island Railroad:

My experience with the metric system dated from early childhood and first school training, when I had a thorough knowledge of it. . . . A change from the present system of measurements, in my mind, would work great hardship on the general run of engineers.

In the reply to Mr. Christie will be found the opinions of a group of men who have had very unusual opportunities for acquiring familiarity with both systems, and who have been unable to discover the great advantages which Mr. Miller thinks must exist, but which he is unable to point out.

Finally, the superintendent of the works of Willans & Robinson, Mr. J. E. Shore, writes as the result of ten years of experience with the two systems:

Broadly speaking, I do not see any advantage arising to the shops from the use of metric measurements if the English inch be divided into tenths.

Like all the others, Mr. Miller defends the proposed law by showing how little it will do; and, again, like all the others, he ignores the fact that compelling its use by the government departments compels its use by those who deal with the departments. Using the system in specification figures as described by Mr. Miller, and then calling this the adoption of the metric system, appears to me the most screaming of farces. What will such a course accomplish?

Of course Mr. Miller is entirely mistaken in thinking that I regard this bill as compulsory in transactions other than with the government.

Mr. C. J. H. Woodbury.—The convenience of unity in a system of weights and measures is such that it may be considered axiomatic that it would be preferable if other things were equal. The change from one system to another would be undoubtedly burdensome in many particulars, but perhaps not more so than has been the case in those countries which have adopted the metric system. The permissive use of the metric system under the present United States law allows those who prefer, to make use of it, and if its merits are greater than those in existence, it will in time prevail; but I have failed to receive information of any existing emergencies which require legislation of compulsory nature to force the change, and believe that such action would not be desirable until the metric system was the controlling one. I do not believe that the metric system is any more of an impediment to commerce than the different money standards prevailing in various countries.

There is, however, an opportunity for a unification of standards for textiles, which can be adopted without hardship, and at the same time render a great convenience in the manufacture of textiles, particularly as at the present time many of the fabrics are composed of mixed material. The systems of yarn numbering vary with the textile materials, and the difference in the basis renders the use of these variable methods of numbering yarn confusing to anyone engaged in weaving who is obliged to purchase the yarns of the material which they do not manufacture.

An International Congress on the Unification of Yarn Numbering was held in connection with the International Exposition at Paris, on September 3 and 4, 1900, and has resulted in the formation of a permanent bureau, of which M. Paul Fleury, 9 rue d'Uzes, Paris, is general secretary. The proposed system for numbering the yarns of all fibres, excepting reeled silk, is that one metre of the yarn would weigh one gramme, and this could be changed to English cotton equivalents by multiplying the International numbering by .59; or, on the other hand, the International standard could be changed to the English cotton standard by multiplying the English numbering by 1.69. While the results of this conference were ultimately adopted by textile manufacturers in Europe, the opposition of English manufacturers prevented the unanimous adoption of the proposed International standard, although many English trade organizations have gone on record as favoring the same, and the present organization proposes to bring this up as a matter of diplomacy between the various cotton manufacturing countries.

The difficulties in the way of the adoption of such an International standard are not as serious as those of other weights and measures, because the limitations of the character of fibres render textile numbering an approximate line of manufacture, as the numbers of yarn change, not merely with the varying characteristics of the fibre which is being spun, but also either the drying or absorption of moisture from the air; and it is a well-known fact that yarns that are on sale are brought to the exact number by drying or by storage in damp cellars. In manufacturing companies, if a mill wished to spin No. 60 on English standard, this would be the equivalent of 102 on the International standard.

The report of this Congress was translated for the New England Cotton Manufacturers' Association, and is contained in vol. lxx. of the *Transactions*, beginning on page 257.

Mr. W. W. Crosby.—Mr. Halsey devotes considerable attention to the textile industries, the subject-matter being supplied from an outside source. This Society, while interested in all engineering subjects, cannot go into the detail of measuring yarns and fabrics with such interest as would the New England Cotton Manufacturers' Association or the National Association of Wool Manufacturers; but as the subject is introduced, it is not altogether out of place to bring in some side lights.

The writer has been connected with the Lowell Textile School at Lowell, Massachusetts, for nearly six years, as instructor and principal, and has had intimate connection with many mills and manufacturers during that time. The problems connected with the textile industries have been studied at close range by a corps of instructors who are specialists, each in his line, not merely from a theoretical standpoint, but from that of actual practice, and mill experience as well; nor has that experience been drawn from an isolated locality, but from north and south, from our side of the Atlantic and across the water. The school is provided with a complete outfit of machinery for cleaning the fibre, spinning the yarn, weaving, dyeing and finishing the fabric; the work hitherto has been carried on in rented quarters, but we are now moving to a plant of our own, embracing eight acres of land and over 92,000 feet of floor space. The development of the courses of study to keep pace with all this material growth has necessitated the most careful scrutiny, that the component parts should be sound, and that no energy should be wasted, but that all should tend toward the accomplishment of the greatest amount in the shortest time. No one detail has stood out more prominently than the incongruity of measurements, and the amount of time spent in dreary transformations of units; for instance:

No. 1 cotton yarn	contains	840	yards	per pound
No. 1 worsted "	"	560	"	" "
No. 1 woollen "	"	1,600	"	"

if on the run system, 300 yards if on the cut system.

Then there are grain systems, dram systems, and many others; but I name only these now, for I shall quote later an article with all these details in full. It is not difficult to see, however, if you wish to use a worsted face with woollen backing and perhaps cotton binders, that there is a waste of time in reducing the units to a common denominator, and a much increased opportunity for mistakes to enter and errors to be made.

When all questions of antipathy and personal temporary inconvenience are left out of account, and the true engineering side of the case taken up, there is never any hesitancy in discarding the indirect, complicated and possibly ambiguous method for that which arrives at a result in a clean-cut, if novel, method, though the latter may necessitate at the outset some extra mental stimulus; no manufacturer hesitates to throw into the scrap heap an otherwise good machine, when one which is capable of better work comes into the market and can show a greater return on the investment.

Whatever the experience of other nations in endeavoring to emerge from the dark ages of uncertain measures, the fact remains that there was a situation which for them was bad, and they sought relief. If we can learn lessons from their experience, well and good; but we surely cannot allow our eyes to be blinded to the main issue by any fog of "hodgepodgeisms" due to attempts to correct a part of an evil without the power to make the movement complete. By this I mean that the best sort of an argument for the unification of yarn numbers is found in the quotation from the *Textile World* article (October, 1902), where it starts out by saying that the raw material was purchased by *the English pound.* The trade in Germany needed the English yarns, and had to take them as furnished in English counts; the intermediate calculations were made metrically, and there was excellent opportunity for a confusion of units in the calculations. The quotation from the Lowell *Textile Journal* to follow will show how ridiculously simple all ordinary calculations for fabrics become when made consistently metrically. The Germans attempted to move a part without being able to move the whole of their system; for the English, who made the yarns, were not easily stirred. But they are stirring now, as I shall show later, and our own manufacturers are stirring. The New England Cotton Manufacturers' Association is on record as favoring the International standard (the basis is the metric system: 1,000 metres, weighing 1 kilogramme, being No. 1; 2,000 metres, weighing 1 kilogramme, being No. 2) for numbering yarns, and I know many prominent woollen and worsted manufacturers who are heartily in favor of it. The trustees of the Lowell Textile School have made this the standard system for the school, even though we have to teach the relations of the pound, yard, etc. Here I quote from the Lowell *Textile Journal* an article written by Fenwick Umpleby, Head Instructor in Textile

Design at the Lowell Textile School, and I. Walwin Barr, his assistant.

In a recent issue of a current textile magazine an article appeared, written by the editor, setting forth the relative advantages and disadvantages of the metric and English systems, to the detriment of the former system. Believing firmly that a new system is necessary, and that the metric system has so many points of superiority as to make its use desirable, the following article was written in its support as an answer to the other article.

The subject chosen was "Cloth Analysis by English and Metric Systems," and the comparison was so carried out as to disprove the convenience and utility of the latter system. In the first place the writer chose a die for cutting the English sample, with dimensions of 1.8 inches wide by 2.4 inches long. This use of decimals is an acknowledgment of their convenience not consistent with the argument, which is, English system against decimals or metric system. [No! Decimals were not invented to go with the metric system. Any one may use them.—F. A. H.] That these dimensions were not taken at random, however, will be clearly seen when the method of figuring is analyzed further. When multiplied together they give an area of 4.32 square inches, equivalent to one inch wide by 4.32 inches long, giving the straight line system, and 4.32 is a number in constant use in the cotton and spun silk trade, representing, as it does, the number of inches to the grain of No. 1 yarn, the standard number of yards being 840.

$$840 \times 36 = 30{,}240 \text{ in. per lb.} \div 7{,}000 \text{ grs. per lb.} = 4.32 \text{ in. per gr.}$$

From this point it is easy to see that the number of warp threads per inch of any one kind, divided by their weight in grains of that warp yarn in the sample, will give the counts of the yarn, as each thread is 4.32 long.

Ordinarily the formula would be:

$$\frac{\text{Inches of yarn} \times 7{,}000}{840 \text{ yds.} \times 36 \text{ in.} \times \text{weight of yarn}}$$

Or

$$\frac{\text{Threads per inch} \times \text{length} \times 7{,}000}{840 \times 36 \times \text{weight of above yarn}}$$

The example given, carried out under this formula would read:

$$\frac{31 \times \cancel{4.32} \times \overset{\cancel{8.33}}{\cancel{7000}}}{\cancel{840} \times \underset{\cancel{4.32}}{\cancel{36}} \times 1.8} = 17.22,$$

thus showing that when cancelled out the only quantities left are the threads per inch in the dividend and the weight in the divisor; therefore, with the die of the dimensions given, the threads per inch of any kind of yarn divided by the weight of that kind of yarn in the sample will give the counts.

That this method is a very direct and satisfactory one cannot be gainsaid, but it must be conceded that there is first a considerable number of figures employed in working out the constant, and that even then this constant applies only to cotton and spun silk yarns, and when the die constructed from it as a basis is used with fabrics composed of other materials, the answers are given in cotton counts, which must be converted into the system of numbering under which that material may be classed. With worsted this is very simple, because the cotton standard number, 840, is just one-half greater than the worsted standard number, 560, and consequently the worsted count is just one-half greater; therefore adding to the answer obtained from the formula one-half of itself would give the worsted count. When transferring the counts to woollen, they would first be multiplied by 840, and then divided by the yards per pound of one run, cut, skein, or whatever system may be in use, about which systems more will be written later.

The first formula given worked out to a constant is:

$$\frac{\text{Inches of yarn} \times 7{,}000}{840 \text{ yds.} \times 36 \text{ in.} \times \text{weight of yarn}}$$

Or

$$\frac{7{,}000 \text{ grs.}}{840 \times 36} = .2314 \text{ grs. per in.}$$

$$\frac{\text{Inches of yarn} \times .2314}{\text{weight of yarn}}$$

and this is in use regularly for figuring the counts of cotton yarn from a certain number of inches and their weight.

Again there is a considerable number of figures required to work out the constant, as in working out the other constant, for which the writer referred to gave no credit in his article. In figuring for comparison, nothing should be omitted to the detriment of either metric or English system, because 2 and 2 are 4, no matter under what system. We agree with "Is it worth while" as to the size of a die to be used, in that a die 2 inches square will give more uniform results than a die 1 inch square, and never knew of a smaller die than the latter being used for any practical textile calculations.

The writer also states that it is a fact "that a distance approximating the English inch is best suited for gauging the set of most woollen and cotton fabrics." If so, then 25 millimetres will more nearly approach the distance named than 3 centimetres, which he uses; but we think 5 centimetres to be still better as a measurement. He states that a die should be used to cut the samples having an area cf about 4 square inches, "because this is a size not so large as to make the unravelling of the threads unnecessarily laborious, nor so small as to make error probable." A metric die was used, 40 millimetres by 50 millimetres, giving an area of 2,000 square millimetres, or 20 square centimetres, an area a little less than 4 square inches. We have used a die 5 centimetres square, giving an area 25 square centimetres, this too being slightly less than 4 square inches; but its use proves that it will give good results, with the following formula as the method of use:

$$\frac{\text{Threads in sample} \times 5 \text{ (cm. long)}}{\text{Weight in centigrammes}}$$

The sample would be cut with the die, then ravelled out, and the number of threads of each different kind counted and weighed. Then the number of threads multiplied by 5 centimetres, the length of each thread, will give the total length of the thread in centimetres, and dividing this by the weight in centigrammes will givethe counts. This in itself is as simple as the straight line system, and without any special effort to make a die which will fit the fabric.

At one point it is stated, "We have previously discovered that neither the French centimetre nor the decimetre is suited for gauging the "set" of textile fabrics, and now find that the use of the metric system gives us an area too small for the determination of yarn sizes with an accuracy sufficient for mill work." This statement is absurd on the face of it, because the area is no more limited when measured by a metric rule than by an English rule. Granting that the centimetre is too short a space to use for measuring the set, we fail to see why a decimetre is not well suited for that purpose; or, if it is considered too long, there are plenty of subdivisions which can be used, the 5 centimetres as given above answering the purpose in every way. A glance at the accompanying cuts will give the reader an idea as to how little actual difference there is between a die 1 inch square and a die 25 millimetres square, or between a die 2 inches square and one 5 centimetres square.

Personally, we favor a square die, using that die as a measurement for the set by picking out and counting the threads stamped out by it, rather than using a die which fits one fabric (but not others), and then counting the threads to a certain space in the cloth, and using in combination with the total length and weight formed in the sample. The metric sample, as before mentioned, was 40 millimetres by 50 millimetres, and gave an area of 2,000 square millimetres equivalent, 2 centimetres wide by 10 centimetres long. Then figuring from the data which was formed, as follows: for worsted, 74 threads per 3 centimetres, the worsted warp in the sample weighing 20 centigrammes.

Then with 74 threads per 3 centimetres by 10 centimetres long would be 740 centimetres by $\frac{2}{3}$ for 2 centimetres = 493 centimetres of worsted in the metric sample, and dividing 493 by 20 gives 24.65, or 25 as the metric counts of the worsted. Of course, in figuring the cotton warp and the filling the same method is used.

To find the weight of a yard of cloth in ounces a constant has again been used, and no credit given for the figures necessary to produce it, which are shown in the formula:

$$\frac{55\frac{1}{2}\text{ in.} \times 36\text{ in. the weight of sample}}{432\text{ in.} \times 437.5\text{ (grs. per oz.)}}$$

This formula worked out gives 1.05 × weight of sample = weight per yard.

The constant 1.05 is for one width only, 55½ inches, the statement being made that the constant is worked out once for each width and stamped upon the side of the die. If the constants were worked out for each width from 20 inches to 60 inches by eighths of an inch, there would be no less than 320 constants, which would require the side of a die a foot square to hold them. In figuring out any cloth by the use of constants a certain allowance should be made for the figures required to produce them, if a just comparison is to result.

For finding the metric weight per metre of cloth no constant is necessary. The sample, containing an area equivalent to 2 centimetres wide × 10 centimetres, or one decimetre long, weighs 62 centigrammes, or 31 centigrammes per centimetre wide for each decimetre in length. For the metre length the cloth would weigh 31 decigrammes per centimetre in width, and as the cloth is 14 decimetres, or 140 centimetres wide, the weight is 31 decigrammes multiplied by 140 centimetres, giving 4,340 decigrammes per metre of cloth. Reducing the decigrammes to grammes by pointing off one place gives as an answer 434 grammes per metre of cloth.

It is hard to see wherein the metric system would suffer at all in the comparison if due credit had been given at proper points for figures where only results are shown.

The article then goes on to say that the English system is a natural system based on the dimensions of the body, the height, size of hand and foot. When were there ever two human beings of the same dimensions? How then, could they be standardized? As for coming from the dim past, one could easily believe that. Many superstitions were handed down from the dim past, which had equally good reasons for existing, but which have long since been discarded. And as for quoting the opinion of John Quincy Adams, the gentleman had the reputation of being a brilliant mathematician, but we fail to see why an opinion expressed early in the last century is at all acceptable in a discussion of present-day affairs in matters such as is under discussion, or any others.

In another paragraph reading partially as follows, " We may be able to simplify our English textile standards, to apply to them the decimal divisions to a greater extent than at present, to find simpler and more direct methods of calculation than any now used," the writer practically admits the need of a new standard, and suggests that decimals be applied to the English system. No standard is as simple as the metric, and how immeasurably superior is a true decimal system to a hashed-up English system with decimal divisions.

A few remarks as to the systems in use in America at the present time would not come amiss at this point. For cotton, probably 840 yards is the generally accepted standard number of yards per pound for No. 1, and for worsted 560. For linen, jute and ramie fibre, 300 yards per pound for No. 1's are used. For spun silk, 840 is used. For raw silk, three different systems are used: the tram silk system, 20,000 yards weighing one ounce, is No. 1; 20,000 yards weighing two ounces is No. 2, etc. The dram system, 1,000 yards per dram, 16,000 yards per ounce, or 256,000 yards per pound, equal No. 1, and 1,000 yards weighing two drams being 2 dram silk, etc. Then the denier system, where 400 French ells = 476 metres = 520 yards, is used as a standard measurement, and whatever the weight in deniers, that number is the counts. 1 ounce = 533.33 deniers. When we come to the woollen systems, there we find our " ungodly disorder." According to the location or to the personal preferences of those in control, the various systems used are, 1,600 yards per pound for 1 run woollen, 300 yards per pound for 1 cut woollen, 256 yards per pound for 1 skein woollen, 240 yards per pound for 1 hank woollen; and another system, where the weight in grains of 20 yards is taken as the counts, i.e. if 20 yards weigh 1 grain it is No. 1; if 20 yards weigh 2 grains it is No. 2, etc. Here, then, is ample proof of " ungodly disorder" in our own country, there being no need to look across to Europe to find such. Here are 12 different systems in use: 1 for cotton, 1 for worsted, 4 for silk, 1 for jute, linen and ramie fibre, and 5 for woollen, where one system more simple in every way could and should be used instead. All this, if allowed to, will continue in the same old way; but legislation could make a wonderful change for the better. If, in all public business, all imports and exports, duties, etc., the use of the metric system were to be made compulsory, the change would come gradually and naturally. We do not advocate sudden change or complete turnover, as it were, but if the children at present in school were taught thoroughly to use the metric system—in fact, to think in the metric system—when they came to do the business of the nation the complete change could be made to the lasting benefit of all.

One of the writers of this article has had a wide range of experience in England, Canada and the United States, and is well informed from personal experience as to the state of confusion resulting from the use of so many systems. A short time ago while engaged in conversation with a designer from Europe, where we are told things are all mixed up, he said he could not understand why a nation like the United States, so progressive in other ways, should be so far behind as to be using skeins, hanks, cuts, runs, and the grain system for numbering yarn made from one material.

SAMPLE OF MIXED SUITING.

Width 31½ inches.
96 threads per inch.
48 picks per inch.
Dressed 1 Face 1 Back

System of Warp (Face),	Black Cotton	6		6		=	12
	Slate Worsted	2	2	2	2	=	8
	Blue Worsted	2		2		=	4
							24
System of Warp (Back),							
	Black Cotton	6	2	6	2	=	16
	Slate Cotton	2	2	2	2	=	8
							24

48 threads in pattern x 63 patterns = 3,024 threads.
Face warp 2-30 Black Cotton.
Face warp 2-44 Slate Worsted.
Face warp 2-44 Blue Worsted.
Back warp 1-15 Black Cotton.
Back warp 1-15 Slate Cotton.
Filling in 4-run Black Woolen.

STRAIGHT FIGURING WITHOUT ANY CANCELLATIONS.

2-30 Black Cotton	756 x 16 ÷ 15 x 840	=	.9595 oz.
2-44 Slate Worsted	378 x 16 ÷ 22 x 560	=	.4909 oz.
2-44 Blue Worsted	378 x 16 ÷ 22 x 560	=	.4909 oz.
1-15 Black Cotton	1,008 x 16 ÷ 15 x 840	=	1.28 oz.
1-15 Slate Cotton	504 x 19 ÷ 15 x 840	=	.64 oz.
4-run Black Woolen	31.5 in. x 48 ÷ 4 run	=	3.78 oz.
			7.6413 oz.

THE ABOVE FABRIC FIGURED BY THE METRIC SYSTEM WITHOUT ANY CANCELLATIONS.

8 dm wide.
378 threads per dm.
189 picks per dm.

(Metric) Face warp 2-50 Black Cotton.
Face warp 2-50 Slate Worsted.
Face warp 2-50 Blue Worsted.
Back warp 1-25 Black Cotton.
Back warp 1-25 Slate Woolen.
Filling 13 Woolen

$$\frac{378 \times 8\text{—}3024 \times 1 \text{ metre}}{25 \text{ counts}} = \qquad 120.96 \text{ gm.}$$

$$\frac{189 \text{ pks} \times 8 \times 1}{13 \text{ counts}} = \qquad 116.30 \text{ gm.}$$

237.26 gm.

DETAIL REQUIREMENTS.

Weight of material for 1 metre of warp.

Face Black cotton	756 + 25 =	30.24 grammes.
Face Slate cotton	378 + 25 =	15.12 grammes.
Face Blue cotton	378 + 25 =	15.12 grammes.
Back Black cotton	1008 + 25 =	40.32 grammes.
Back Slate cotton	504 = 23 =	20.16 grammes.
Filling 189 x 8 x 10 + 13	=	116.30
		237.26

1 Metre = 39.37 in. and weighs 237.26 grammes +
28.35 grammes in 1 oz. = .8.37 oz.
Then as 39.37 in. : 36 :: 8.37 : x

$$\frac{8.37 \times 36}{39.37} = 7.63 \text{ oz.}$$

In Bradford, England, is located the most celebrated conditioning house in the world, to which are referred all questions relating to textile fibres, yarns and fabrics for final reports. The manager, Mr. Walter Townsend, is therefore most closely in touch with the textile situation, and is called upon to investigate all manner of cases in this line. The works are equipped most completely with machines for testing condition or moisture, strength, elasticity, staple, dyestuff, in fact, everything that has to do with the make-up of a piece of cloth. Let me quote from a recent letter from Mr. Townsend:

Re Metric and Decimal Systems.—Personally I am a very strong advocate of them and have adopted it entirely *here,* as far as calculations and measurements go in all our conditioning-house work, and of course we all as a staff find an enormous saving of time and an easy checking as to correctness. Our little nation takes it up slowly, but I am glad to say that The Board of Trade in London is very busy on the matter and my friend, Mr. Spencer, a high official there, is very enthusiastic and working with me in preparing tables, scales, reductions, in both weights and measures. I will give you a further report later on as I go to London on this special matter next week. To fight against ignorance, prejudice and old-fashioned customs is (in this country at least) very hard work, but "peg away" is my motto.

Again let me quote from a letter written to Mr. J. H. Reynolds, Principal of the Municipal Technical School of Manchester, England, by Mr. H. E. Wollmer, who, Mr. Reynolds informs me, is the director of the firm, Sir Jacob Behrens & Sons, exporters of yarns.

Thanks for kindly sending me the enclosed letter which I have read with much interest. Last week our Board advised the Indian Government to adopt the metric system of weights, etc., for wool, worsted and silk yarns in preference to the English system, which for some of these yarns seems to be practically unknown in India, whilst the metric or Continental system has been in use there for many years. In fact, some dealers decline to buy their yarns unless made up in the Continental way, and what your friend says is very convincing, respecting the drawbacks of so many systems being in use at the same time. Cotton yarns will have to follow but they will be the last upon the list, as our system is nearly universally in use, and the change will be somewhat disturbing and also very expensive; however, our course is clear.

Under date of March 27, 1902, the *Yorkshire* (England) *Post* printed the following:

WOOLLEN AND SILK YARNS FOR INDIA.

The metric system of count. The Secretary of State for India is asking the Association of Chambers of Commerce to ascertain the views of manufacturers on a question which has arisen regarding the admission of the Continental or metric method of count, as an alternative for the British system, for the marking and description of woollen and silk yarns imported into British India. It seems that some Indian dealers, when invited to give orders for British worsted and wool yarns, have declined to do so unless the yarn is made up on the Continental system; and the customs authorities of India have written to Lord George Hamilton, pointing out that the trade in yarns has passed into foreign hands.

Messrs. Macdonald & Co., of Karachi, wrote to the Chief Collector of Customs in Sind:

The Indian dealers have got so accustomed to the Continental count of worsted wool yarn that they absolutely decline to give orders for the yarn made up according to the British standard of count, and stipulate when giving orders that the yarn must be made up according to the system in vogue on the Continent. It appears that this system of making up suits their looms better than the British standard. If, therefore, the government should decide to insist upon the goods being made up according to the British standard, it appears to us that, for a time at least, trade would be hampered.

Messrs. Volkart Brothers, also of Karachi, write:

The yarns have now come to India, for years, made up according to the metric scale, and the trade has got accustomed to it. Serious difficulties will arise with consumers up-country should the government of India decree that wool yarn must be made up according to the old and little known British worsted scale.

The Government of Calcutta, writing to Lord George Hamilton on the 20th of February, say:

We have permitted for the present the use of the Continental description of count which follows the metric system, as this is said to be more convenient to the trade; but it is possible that there may be objections from the point of view of the English manufacturers. We should, therefore, be glad to learn the views of the English spinners, and let them know that the trade in these yarns is in foreign hands. The orders to use the Continental description of count will be made final if no objection is raised by the British trade.

I have also a copy of the report of Mr. Arthur E. Piggott, Secretary to the Silk Association of Great Britain and Ireland, from which I would quote as follows:

At the annual meeting of this association, held in London on the 26th of February, a communication was reported from the Minister of Commerce of France, asking for the coöperation of this association in securing a uniform system for the numbering of yarn counts, etc., and an expert committee consisting of Mr. Matthew Blair, Mr. Herbert Rowson, Mr. Sydney Thompson, Sir Thomas Wardle, and Mr. George Wigley were appointed to consider the subject, and report to the council.

This report was duly presented to and approved by the council on May 7th, and it was ordered that the report should be printed and circulated to the members of the association and to the Chambers of Commerce in the silk centres.

It was also resolved:

"That the Silk Association recommends the government to adopt the metric system of weights and measures."

I beg, therefore, to send herewith, for your perusal and information, the report of the expert committee, together with an explanatory memorandum on yarn counts which has been prepared by Mr. Matthew Blair, the chairman of the committee, and have to ask for your coöperation in supporting in every way possible the recommendations contained in the report.

Although I am interested in all sides of the question, I did not intend to discuss other than the textile phase; yet I cannot refrain from quoting a letter sent to the American Hide & Leather Co. at Boston, under date of March 25, 1902, from Paris, the matter being brought to my attention by a friend who is connected with this large company, which has a very heavy export trade:

Enclosed you will find report of last meeting held by the Syndicat Général de la Chaussure de France, whereby you will see that the shoe manufacturers of this country have not decided to buy leather otherwise than by metric system (square metre) instead of per foot, which is quite illegal in France. [This is merely a case of translation. See the section of the paper, "The Foreign Trade Argument."—F. A. H.]

This decision will surely affect the sale of all American leathers sold per foot, unless American tanners follow the suggestion of leading shoe manufacturers here to indicate on each skin the French measurement equivalent to that mentioned in square feet.

It occurs to us that you could indicate on the dial of your measuring machine the French measurements as well as the American, so that when leather is measured for France, you could indicate on the skin, French measurement and invoice at so much per square metre instead of per square foot, which would be quite an easy thing to calculate.

We sincerely hope the United States shall, ere long, adopt the metric system already in use nearly over the world, because it would be preferable for all interested parties.

It is, then, no matter of individual whim, or of a few isolated people having to do with the conversion of fibre into fabric, that the question of uniformity of terms and designations is made vital. While the greater proportion of spindles is controlled by England and the United States, to say nothing of the trading between these two countries, the rest of the world is buying not merely the finished product, but that which is partly prepared, for instance, yarns which are to be woven within their own borders; and therefore there is an increasing demand for clear and correct understanding of the nomenclatures.

The various efforts to secure an international standard for yarn numbering have not been successful, because England and the United States, the greatest producers of these goods, were apathetic. Now it is seen these countries are on the alert, and it is hoped that they will not block this important reform. If only we were consistent with our English cousins in our various designations of counts, using as we do pound and yard, we might find some ready means of systematizing the matter; but we are not consistent even among ourselves. In such a case there is no doubt but that the best way is to find the broadest possible ground for a standard, and change everything to that. Such a ground we have in the metric units, where whatever the material of which the yarn is composed, if one metre weighs one gramme it will be designated No. 1; two metres to the gramme, No. 2, etc. The various calculations necessary to the production of a piece of cloth are wonderfully simplified and are of practical, workable value, as has been demonstrated, not by those whose business it is merely to write books and newspaper articles, but by practical mill men who have constructed thousands of pieces of cloth, and have it in mind to do that which will make better fabrics with a minimum expenditure of energy. They have no desire to juggle with figures for the sake of providing argument, but regard their calculations merely as a mill with which to transform data into useful forms. The fewer gears, cams and levers this mill has, the better they like it so long as the product is up to the standard. There are many cases where mills prefer *laissez faire* and to use their own standards, no matter how complicated; they could go along well enough until called upon for a change of product, but their arbitrary standards would then be at a most serious disadvantage.

Our great industrial enterprises have been successful in their combination only by cutting out all wastes both of time and of material, and it is not likely that the textile interests will be far behind when fully alive to the possibilities of saving time in computation.

Mr. F. A. Halsey.—The metric system, as related to the textile industry, can be intelligently discussed by those only who are experts in that industry. The remarks of Professor Crosby and of M. Lamoitier have therefore been sent to Mr. S. S. Dale, editor of the *Textile World*, and the replies to those gentlemen are by him.

Mr. Samuel S. Dale.—While the members of each trade or profession should endeavor to determine the merits of the metric question from their particular point of view, human nature is the same everywhere, and men in one department can acquire valuable information regarding the practical operation of the metric system by observing its effects on trades outside of their own calling.

This Society may not have the personal interest in the textile aspects of the case that is taken by the New England Cotton Manufacturers' Association or the National Association of Wool Manufacturers, but it can profit by the experience of others with the metric system in textile manufacturing as well as can either of the associations above named.

For this reason there is no need to apologize to American engineers for turning a head-light on the metric system in the textile industry.

In the beginning of his paper, Professor Crosby refers in a vague way to the attitude of the New England Cotton Manufacturers' Association and the National Association of Wool Manufacturers toward the metric system. Farther on he comes out flat-footed in regard to the Cotton Association in these words:

> The New England Cotton Manufacturers' Association is on record as favoring the International standard [the base is the metric system] for numbering yarns.

This statement has been spread far and wide, from Belfast to Barcelona, and from Barcelona to Moscow. It was made early at the hearing before the committee on coinage, weights and measures. It appeared in a report made by the National Bureau of Standards at Washington to the British Consul-General at New York, and transmitted by the latter to his government to be published in the English papers, for the purpose of influencing English public opinion in favor of the metric system. And now Professor Crosby conveys the impression that our textile associations favor the metric system. I have not the slightest doubt as to the good faith in making the statement; he is simply repeating what thousands honestly accept, apparently on good authority, and what is, at this moment, being spread throughout Europe as officially endorsed by the Bureau of Standards of the United States Government. As the report has been given such wide publicity, the sooner the truth is known the better. Following is a letter that explains itself:

NEW ENGLAND COTTON MANUFACTURERS' ASSOCIATION, BOSTON, MASS.
January 7, 1903.

DEAR SIR:

In reply to your inquiry of the 6th inst., I would say that the Association never committed itself to the metric system of measuring yarn.

Yours very truly,
C. J. H. WOODBURY,
Secretary.

Neither has the National Association of Wool Manufacturers been committed to the metric system. Its action, so far, has been limited to listening to addresses on the subject by Professors Crosby and Stratton at one of its banquets.

The question of textile weights and measures relates largely, but by no means wholly, to the numbering of yarn, of which there are two general systems. One is based on a fixed weight and variable length, the other on a fixed length and variable weight. The former is used for all textile materials except silk, which is numbered, with the exception of waste silk, by the second system. If 1 pound of cotton yarn is spun 840 yards long, it is called No. 1 yarn; if spun 1,680 yards, or twice as long, it is called No. 2 yarn, the number increasing as the yarn gets finer. This is the English cotton standard.

If 1,000 yards of silk tram or organzine weighs 1 dram, it is called No. 1; if it weighs 2 drams, it is called No. 2, the number increasing as the yarn gets coarser. This system is used in the United States and in England for thrown silk.

Of the four English systems mentioned by Professor Crosby, the 300 yard system is, with the exception of a local and unimportant Austrian standard, the world's single standard for linen, jute, hemp and allied fibres, so that if a spinner of any of these materials in the United States should mention, say, No. 20 yarn to a spinner in Great Britain, France, Germany, Austria, Russia, India, China or Japan, in fact, in any country in the world, both would understand without explanation that the yarn measured 6,000 yards per pound. This system is used to a comparatively small extent for woollen yarn, chiefly in the vicinity of Philadelphia, and the plain lesson to be drawn from its continued local use there, side by side with the commensurable run system (the greater convenience of which will be shown later) is, that methods for numbering yarn, when once rooted, become practically immovable.

Of all the leading branches of textile manufacturing, the linen, hemp and jute industries are the most distinct. These materials are seldom mixed or combined in the same fabric with either cotton, woollen, worsted or silk yarn. Its world-wide standard of 300 yards seldom comes in contact with the remaining three systems cited by Professor Crosby. These, 840 yards for cotton, 560 yards for worsted, and 1,600 yards for carded woollen, are each employed in branches of textile manufacturing, whose processes and machinery are distinct and separate up to and including the preparation of the yarn for weaving. Each branch, cotton, worsted and carded woollen, is a distinct trade. The workmen in each do not require, and usually do not have, any definite knowledge of or skill in the other two. This limits the contact of the three systems to the weaving and designing departments, and to the general management of weaving mills. Fortunately, however, the 840, 560, 300 and 1,600 yard systems have certain relations to each other and to the pound which remove the apparent difficulty of using them together.

First, they are all based on the English yard-pound. This is their chief merit, which I will not dwell on now, as it will be evident when we consider the metric units, but will note their other advantages.

The cotton is just one-half longer than the worsted skein, and the number by the worsted system is therefore larger by just one-half than by the cotton system; that is, No. 20 cotton is equal to No. 30 worsted. The cotton number can likewise be obtained from the worsted number by taking one-third from the latter; that is, No. 30 worsted is No. 20 cotton.

When we come to the 1,600 yard skein, the standard for the carded woollen yarn, we find that No. 1 woollen yarn, measuring 1,600 yards per pound, measures 100 yards per ounce; that No. 2 yarn measures 200 yards per ounce; No. 3½ yarn 350 yards per ounce, the number of the yarn expressing in each case the number of hundred yards per ounce. This facilitates greatly the calculation of the weight per yard which is expressed in ounces. If a yard of cloth contains, say, 4,000 yards of 3-run warp yarn, a simple division will show that the warp weighs 13⅓ ounces per yard. This is such an advantage that the best mill practice uses the run system for calculating per yard, not only the weight of carded woollen yarn, but also that of cotton and worsted. For the last two this necessitates a conversion, which can be made mentally by the factor .5¼ for cotton, from which the worsted number is obtained as already explained. This is the practice of the mill and not a theory of the class-room.

I do not wish to be understood as claiming that this system, involving the use of four methods of yarn numbering, is the best that could be devised. If we could start anew and establish a new system of yarn numbering, it is certain that mill experience with the present methods would dictate but one base for all textile materials except silk. It is equally certain that that new system would not be the metric. Evidence as to this last statement will be given further on. The point I wish to make plain now is that our present yarn units, which are rooted and grounded in every mill in the world where textile fibres are spun into yarn, and which the experience of Europe teaches us cannot be eradicated, offer decided facilities for their joint use. They are all based on the yard and pound, and are easily commensurable.

Professor Crosby, after citing our yarn systems, vaguely refers to a "clean-cut" method which, he says, may necessitate at the outset some mental stimulus, but which possesses great and manifest advantages over our present methods. Let us call a spade a spade. He means the metric system. Now I deny that the metric or any other system of numbering yarn necessitates a mental stimulus at the outset. The metric system of yarn numbering is simply the substitution of 1,000 metres for the 840 yards of the English cotton system, and the kilogram for the English pound. In other words, if a kilogram of yarn measures 20,000 metres, it is No. 20 yarn. That is all there is to the metric or any other system of numbering yarn based on a fixed weight and variable length. The "mental stimulus," as Professor Crosby calls it, but rather the mental demoralization, results from the attempt to use the metric side by side with the English units, and is due to the incommensurability of the two.

The size of the yarn is one of the most important elements in textile structures. The selection of the raw material and the adjustment and construction of nearly every machine in the mill depend on the size of the yarn to be made. The experience and thought of every textile worker, no matter how mechanical his work may be, is rooted to the *number of the yarn*. This explains why yarn numbers have passed unchanged through a century of upheaval in old French units of weights and measures. The idea that the experience in America would be different is so obviously opposed to manifest truth as to deserve no attention.

What then are to be the bases of American yarn counts in that remote era when the use of the metric system in the departments of the United States Government has, by a species of mental suggestion, led the American people to abandon all use of the English yard and pound, and those units have disappeared forever? Following is the reply:

Cotton	skeins of	1,693.63	metres	per	kilogramme.
Worsted	" "	1,129.09	"	"	"
Woollen	" "	3,226.	"	"	"
Linen	" "	604.85	"	"	"

Bear in mind that these are the awkward expressions of the second stage of metric development, which comes after the first "transition" period during which the yard and pound have not been driven or coaxed out, and when it would be necessary to retain the metric equivalents not for the skein only, but also for the pound. During this first period, in which France still remains, the bases of our four forms of yarn numbering would be expressed as follows:

Cotton, now 840 yds. per lb.; then 768.09 metres per 453.59 grammes.
Worsted, now 560 yds. per lb.; then 512.05 metres per 453.59 grammes.
Woollen, now 1,600 yds. per lb.; then 1,463.04 metres per 453.59 grammes.
Linen, now 300 yds. per lb.; then 274.31 metres per 453.59 grammes.

This is not theory. The last-named metric equivalents of our English cotton, worsted and linen yarn units are taken from Brüggemann, Die Nötigen Eigenschaften der Gespinste, and show European practice to-day.

The first two stages of this process of evolution can now be found in France. In Elbœuf the numbering of carded yarn is based on a fixed weight of 40 sous (an old unit of weight) or its equivalent, 500 grammes, and a variable length expressed in skeins of 3,600 metres. This is the first stage. Passing to Roubaix, for example, we find the evolution in the second stage, the fixed weight being the kilogramme and the variable length expressed in skeins of 714 metres.

The third stage in France is the use of the system based on the 1,000-metre skein and the kilogramme. The last-named is the only one that is metric, and has been introduced to some extent in the woollen industry, but in the other branches is used so little as to hardly warrant the statement that the last stage has begun.

Thus the experience of Europe teaches us that the "clean-cut" method of Professor Crosby will first give us a 768.09-metre 453.59-gramme cotton yarn system for centuries, with equally absurd bases for each of our other systems. If we escape from them we shall then have another era with the absurdities reduced one-half; in the meantime, endless confusion. Compare these expressions with our present clean-cut skeins of 300, 560, 840 and 1,600 yards, all based on the English yard-pound. Is Professor Crosby's remedy for what he calls the "incongruity of measurements" worth while?

There is no question as to the correctness of the professor's conclusion that the reference to the English pound in the October article in the *Textile World* is the "best sort of an argument for the unification of yarn numbers," and as the English pound dominates the textile world, it is equally certain that the easiest way of reaching unification is the adoption of that pound as the basis of yarn numbering; in fact, it is already the standard for three-quarters of the world's textile industry.

We next meet with the statement that the English spinners "are stirring and our own manufacturers are stirring" in their efforts to adopt the metric system. Then comes the claim as to the New England Cotton Manufacturers Association, which has already been disposed of. Our textile manufacturers are certainly "stirring," but it is to make a living with a thirty-six inch yard and a sixteen-ounce pound. The metric system is not thought of by the great majority of manufacturers. They have no time to think of such a preposterous proposition as that of changing the yard to 39⅜ inches minus, and the pound to 17⅝ ounces plus. This indifference is conclusively shown by their responses to requests for opinions on the metric question. The *Textile World* addressed copies of the October issué containing the article, "It Is Worth While," by Professor Crosby in favor of the metric system, to 1,200 textile manufacturers throughout the country, with a request for replies to these three questions:

1. Do you favor the adoption of the metric system?
2. Are you opposed to it?
3. Do you favor postponing action until the subject has been calmly and scientifically investigated (as in 1817 and in 1866)?

Fifty-four replies were received, of which 17 were in favor, 18 opposed, and 19 favored delay; 17 out of 1,200 represents the "stirring" that has so impressed the Professor.

In this matter of weights and measures the preferences and opinions of employers do not control. There is probably not one textile manufacturer in France, Germany, Austria, Italy and Spain, who does not ardently favor the use of the metric system. No one should deceive himself by thinking that this unanimity is due to the merits of the metric system. They favor it because it offers the only way of escape from the chaos of local standards in which Europe is involved. They are, however, powerless to bring this result about, owing, among many other things, to the familiarity of their employés with the old units. If Professor Crosby will go among the textile operatives in this country, the wool sorters, carders, combers, drawers, spinners, twisters, spoolers, warpers, weavers, dyers, bleachers and finishers, and ask for opinions on the metric system, he will find (instead of the stirring of 17 out of 1,200) a complete state of coma. Textile weights and measures are regulated by the millions who create wealth in the mill instead of by the hundreds that count that wealth in dollars and cents in the counting house.

Professor Crosby makes a reply by the chief instructor and his assistant in the Lowell Textile School to the October article, "English versus Metric," a part of his own reply to Mr. Halsey's paper (No. 971). It is safe to say that three-quarters of the school article is wholly unintelligible unless read in connection with that to which it is offered as a reply.

To make clear what the Lowell instructors are aiming at, I annex extracts from "English versus Metric," as follows:

ENGLISH VERSUS METRIC IN CLOTH ANALYSIS.

(From *Textile World*, October, 1902.)

A straight line measures the shortest distance between two points.—Euclid.

The claim, unfortified by figures, was made before the Committee on Coinage, Weights and Measures at Washington, that the metric system would greatly simplify calculations in the analysis of textile fabrics and thus save much labor now made necessary by our present system of weights and measures.

Let us put this to a practical test.

We will analyze two pieces of the same fabric, one by the English, the other by the metric system.

At Fig. 111 is the sample to be analyzed. At Fig. 112 is a vest made from this cloth by an English tailor. At Fig. 113 is the residue of a sample of the goods after extracting the wool with caustic alkali. The cloth is known as a union fabric, that is, composed of yarns made from different materials: in this case cotton and worsted.

For the English system we will make the die 1 8-10 by 2 4-10 inches, with an area of 4.32 square inches.

For the metric system we will make the die 40 mm by 50 mm.

The next step is to find the "set," that is, the number of threads in a given space. By the English system this is indicated by the threads of warp or filling per inch.

It may be a mere coincidence, yet is nevertheless a fact, that a distance approximating the English inch is best suited for gauging the "set" of most woolen and cotton fabrics. It is not so long as to make the counting of the threads too laborious. It is not so short as to cause a serious error by discarding a fraction of a thread.

When we turn to the metric system, however, we find no unit of length corresponding even approximately to the English inch. The centimeter is less than 4-10 of an inch, and from this unit we jump by the decimal step to the decimeter which is equal to about 4 inches.

In the first case the metric unit is too short: in the second much too long for computing the set of ordinary textile fabrics.

That this is a practical difficulty with the metric system is shown by the following extract from Methodik der Bindungslehre und Decomposition fuer

FIG. 111.

FIG. 112. FIG. 113.

Schaftweberei, a standard German work on weaving by Franz Donat, Professor at the Royal Weaving School of Reichenberg:

"The threads in warp and filling are gauged by the number per decimeter. The use of the centimeter is unsafe (unsicher), because from 1-2 to 1 thread (even more in silk goods) may easily be overlooked."

Another indication of this defect is the fact that the French weaver, over one hundred years after the birth of the metric system, is still found using the inch for counting picks."

In the English sample, we find in the warp 62 worsted and 31 cotton threads per inch: in the filling 130 cotton threads per inch.

In the metric sample we count in the warp 74 worsted and 37 cotton threads per 3 cm: in the filling 153 cotton filling threads per 3 cm.

The next step is to determine the size of the yarn in warp and filling.

We ravel out both samples, keeping each kind of yarn separate. In the English sample the worsted warp weighs 4 2-10 grains, the cotton warp 1 8-10

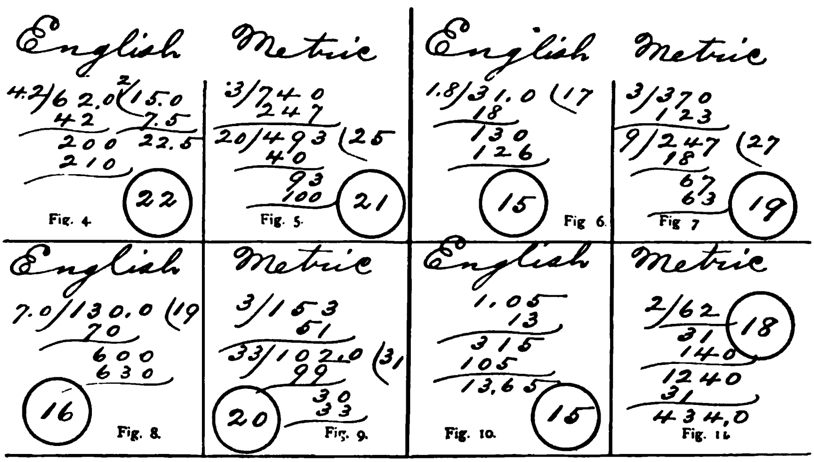


Fig. 114

grains, and the cotton filling 7 grains. In the metric sample the worsted warp weighs 20 cg, the cotton warp 9 cg, and the cotton filling 33 cg.

We now calculate the size of each kind of yarn by each system as follows (see Fig. 114):

Worsted Warp: English, Fig. 4, 22 figures: Metric, Fig. 5, 21 figures.

Cotton Warp: English, Fig. 6, 15 figures: Metric, Fig. 7, 19 figures.

Cotton Filling: English, Fig. 8, 16 figures: Metric, Fig. 9, 20 figures.

The total weight of the English sample is 13 grains, and with 15 figures we find the weight of the goods to be 13 6-10 ounces per yard 55 1-8 inches wide (Fig. 10).

We find that the metric sample weighs 62 cg, and with 18 figures we find the weight of the cloth to be 434 grams per meter 140 cm wide (Fig. 11).

The English constant for the weight per yard is calculated once for each width of goods and stamped on the side of the die. This answers for all subsequent analyses. The metric constants for the die we have used are 10 and the width of the goods in centimeters.

Summing up the calculations we have made, we find 68 figures used with the English and 78 with the metric system.

In making these analyses we have used the decimal system for the metric sample, and what we will style the "straight line" method for the English sample. The operations show that the metric method requires 10 more figures than the "straight line" or English method.

The "straight line" method can, of course, be applied to the metric weights and measures, and the calculations then made as easily as with the English standards, but this can be done only by using a sample measuring 25 mm by 40 mm (approximately 1 in. x 1 5-8 in.), and at the sacrifice of accuracy in the analysis. Experience has demonstrated that a cloth sample with an area of 1 5-8 square inches is much too small for the analysis of union fabrics, in which there are often found several kinds of yarn, some in very small quantities.

We have previously discovered that neither the French centimeter nor the decimeter is suited for guaging the "set" of textile fabrics, and now find that the use of the metric system gives us an area too small for the determination of the yarn sizes with an accuracy sufficient for mill work.

Are these things wholly accidental? The English system comes to us from the dim past, and its standards were based by our rude ancestors on the dimensions of the human body, the height, the size of the hand, arm and foot. It is a natural system.

The French or metric is essentially an artificial system, derived from a failure to determine the 10,000,000th part of the distance between the equator and the North Pole, via Paris.

There are pure English and mixed (English and metric) estimates of cost used in the textile industry to-day. It will be sufficient here to consider the mixed estimate used in the so-called metric countries.

In Mr. Halsey's paper is shown, paragraph 9, a German estimate of the cost of a worsted cloth.

Study this estimate of cost for a few moments, calmly if possible.

(See Mr. Halsey's paper for description of processes.)

Not only is this single English textile standard in use throughout the world, but it is maintained by vast natural force. Consider what a bulwark for the English system of yarn numbering is the single fact that practically all of the raw cotton grown on earth is sold to the mills by the English pound. Acts of Congress cannot resist such forces, but to be of avail must take them into account.

We may be able to simplify our English textile standards, to apply to them the decimal divisions to a greater extent than at present, to find simpler and more direct methods of calculation than any now used, but a solid front should be presented against the pollution of the leading textile standard of the world with the French meter and gram.

France and Germany give us an object lesson as to what such pollution means. There are not lacking signs that the really practical men in the French and German textile industry are turning from the metric and accepting the English standard as a necessity.

Let us not gaze at the metric stars and neglect to till the English soil.

The school article starts out with the assertion that the use of decimals is inconsistent with the argument against the metric system. The absurdity of such a pretence requires no demonstration to engineers, but for the benefit of the two writers making the claim, it may be well to state here that the decimal system was brought from Arabia into Europe about 900 years ago; that the metric system was established 800 years later and made decimal because the Arabic notation was then so firmly established as to make a system with any other exclusive division an impossibility, and that decimals are now used in cloth analysis because they are the basis of our notation, and not because the French make as much of their metric system decimal as natural laws allow.

Down to the sixth paragraph the article is a labored attempt to explain that the size of the English die was not selected at random. The English number of cotton yarn is expressed by the pound in skeins of 840 yards; by the ounce in skeins of $\frac{1}{16}$ of that length, or 52½ yards; by the grain in skeins of $\frac{1}{7000}$ of the first length, or 4.32 inches. The metric number is expressed by the kilogram in skeins of 1,000 yards; by the gram, in skeins of 1 metre; by the decigram, in skeins of 1 decimetre; by the centigram, in skeins of 1 centimetre.

In cloth analysis the weight by the English system is expressed in grains, and the area of the sample is made 4.32 inches in order that each *thread per inch may represent* in the whole sample a cotton skein by the grain system above-mentioned, which is 4.32 inches long. Then a simple division of the number of threads per inch (which is the number of skeins in the whole sample) by the grain weight of the yarn in the sample, gives the skeins per grain, in other words the number or count of the yarn.

Exactly the same method is adopted for the metric system as far as the size of the units and the practical requirements of the work allow. If we weigh by the decigram, it is necessary to select a sample 1 decimetre square; this is altogether too large (about 15½ sq. in.) as the ravelling of so much cloth would require too much time and labor, and the samples available for analysis are usually much smaller. If we measure by the next smaller unit, the centigram, the area of the sample must be $\frac{1}{100}$ of the square decimetre (1 square centimetre), or about $\frac{1}{6}$ of a square inch; this is altogether too small, as the weight of the quantities of the different kinds of yarn would be so small as to make a very slight error in weighing a very serious one in the final results.

Thus, it is seen that the metric units are either too small or too large to enable the calculations of the yarn numbers to be made with a single operation, as is possible by the English system.

In the calculations in the October article, the metric system was favored by assuming 10 centimetres as the metric area for the simplest operations. This is not, strictly speaking, the case, that area being ten times too large. It is, nevertheless, still too small for practical mill work, and it was necessary to make it 20 centimetres on that account, even this area being smaller than is desirable. It was adopted in those calculations in order to favor the metric side of the question, against which the argument was directed, although this course necessitated the omission of decimal points in the metric calculations that the mercy shown to the metric system might not be readily discovered. As the critics have not acknowledged the leniency thus shown, it is perhaps best to state now in full the defects of the metric units in cloth analysis.

The sixth paragraph begins with a grudging admission that the straight line method in the October article "is a very direct and satisfactory one," and continues with an equally awkward confession of the commensurability of English units, winding up with a grim determination to show the English system in the worst possible light by ignoring the ratio .5¼, in converting cotton into woollen counts and by using a formula that should appear only in a primer of cloth analysis.

On page 541 the Lowell instructors announce one point on which they agree with "Is It Worth While?" but in the same breath claim that calculation of some mysterious "constant" should be included in the calculation of each yarn size. Now, there is no constant other than the basic skein used in calculating the English count. The 4.32 inches is the unchanging length of the skein in 1 grain, and calculating it in each case is no more necessary than is the calculation of the value of π whenever the circumference of a circle is reckoned from the diameter, or the demonstration of the Pythagorean proposition whenever one side of a right angle triangle is calculated from the other two. The anxiety to have the English skein calculated in each case by an awkward formula is in marked contrast to their apparent satisfaction with the arbitrary constants that the unsuitable length of the centimetre and the decimetre make it necessary to inject into the metric calculations.

Page 542 should be read carefully in connection with the October article. One sentence is isolated and ridiculed although it refers to the subject-matter of the three preceding paragraphs. This (in connection with the fact that the school article was submitted without the October article) sheds something more than a side light on the discusion.

The ire of the writers is aroused on page 542 because of the adoption of mill practice in calculating the weight per yard, and the curious theory is advánced that a constant must be calculated for each width by eighths of an inch. It is enough to state in reply that commercial widths of finished cloths are expressed almost exclusively in even inches, and that the constants for them can be easily stamped on the die. This is not necessary, however, as each grain in the English sample is equivalent to 1 ounce per yard 52½ inches wide; from the weight of the sample in grains the weight for any width can be calculated by two operations.

We have already observed the solicitude of these writers that the basic formulas for the English operations should be reckoned for each problem. On page 542 is found their application of this theory to metric operations. The area of the metric sample (2 cm. x 10 cm.) and its weight are each divided into halves to begin with. One half is then stretched out to 10 times its length, and the weight alsò increased in the same proportion. The weight is then multiplied by 140, and then divided by 10 to determine the weight of a metre of cloth. All of these operations are explained in detail to show why no constant is required with the metric system! The very next paragraph leads off with the self-satisfied announcement that "it is hard to see wherein the metric system would suffer if due credit had been given at proper points for figures where only results are shown." Such a vibratory state of mind can be explained only on the theory that the chief instructor wrote alternate paragraphs, leaving the assistant to fill the gaps.

A desire for information is expressed on page 543. For an extended explanation of the origin of weights and measures they are referred to the report on the metric system made to Congress in 1821 by John Quincy Adams. Not only the English words, yard, foot, and ell, and the French pas, coudée, pied, palme, pouce, and doight, but the sizes also of these units prove they were originally based on the dimensions of the human body. The sizes of the units of weights and measures are preserved by bars or blocks of metal, the dimensions of which are equally arbitrary, whether based on the foot of Henry I. (as is said to have been the case of the English foot), or on an approximation of the ten-millionth part of the distance, via Paris, between a vibrating line and a movable point, which man can apparently reach as easily as he can now find the foot of the English king.

The reference on page 543 to John Quincy Adams shows the change of front on the part of the metricists since Adams' opinions on the metric system were made plain by Mr. Halsey's paper. While Adams' report was buried out of sight in the archives of the government, or found only with the greatest difficulty in our leading libraries and on the dusty shelves of second-hand book stores, it was the fashion to hold it up as a "classic in metrology," to quote single phrases from it, and omit entire qualifying paragraphs, to say that "Mr. Adams advised delay until—." Now, when it has been shown that John Quincy Adams opposed the introduction of the metric system into the United States, and that he believed decimal numbers were "not adequate to the wants of man in society," why, John Quincy Adams is a back number! On the same page is announced the discovery of some "admissions," made by reading "English versus Metric," "partially." Reading "partially" is a favorite expedient in advocating the metric cause, but is it worth while?

On page 543 appears the confession that 840 yards "probably" is the generally accepted standard for cotton in this country. Why not say plainly that it not only *is* the only cotton standard used in America, but is the controlling standard in every community on earth where raw cotton is spun into yarn? A little book or sample card received a few weeks ago, published in Bayreuth, Germany, by Otto Holtzhausen, showed 14 lengths of white cotton yarn, ranging from No. 6 to No. 45, mounted on a black ground with the number above each one. In the few explanatory words attached appears this sentence: "Die Nummernbezeichnung ist die Englische." (The counts are English.) This collection is issued for sale to German manufacturers and merchants. Professor Crosby cannot find one American cotton manufacturer whose ideas of yarn sizes are not expressed exactly by this German card. Let him take it to England and he will find every one of the 46,000,000 cotton spindles there spinning yarn by the standard of this Bayreuth card. Take it to France and he will find the French spinners with their minds muddled by the use of both the English system and a French system, which is not metric, but all acquainted with the English numbers on the card. Let him carry it back to Germany, where it was published, then to Switzerland, Holland, Belgium, Austria, Italy, Spain, and Russia, and he will find the spinners in these countries using and perfectly familiar with its standard. Journey still further around the globe, and in India he will find the 5,000,000 spindles there spinning cotton yarn by the same standard and at less cost than in any other place on earth. Go still further until China is reached; open the German card and the almond eyes of the celestial cotton spinner will brighten in recognition of its numbers and sizes. Passing northward to Japan he will find that the card likewise indicates the sizes of Japanese yarn. Let him now cross the Pacific to his home in Lowell, and there he will still hear the same monotonous story. Every Lowell, every American cotton mill, is spinning cotton yarn by the 840 yard standard of this German card. He has travelled around the globe and found it to be the world's standard. "End there is none, lo, also, there is no beginning!" Nowhere can he escape from it unless in the class-room of his own school.

If the same journey be made with the 560 yard-pound worsted base, which is the only one used in America, it will be found the exclusive standard in the British Empire, and a leading one in Continental Europe.

Turning to the remarks on page 543, we find equally misleading statements. Other textile materials, such as cotton or wool, are received by the spinner in the form of a tangled mass that is first converted into a coarse sliver or rope, which each successive process up to and including spinning, makes finer. With silk the operation is reversed. The silkworm spins the silk filament to an extreme fineness, which measures on an average about 1,100 miles per pound. In this form it is too fine and delicate to be woven. The first process, therefore, is to double and twist a number of the cocoon filaments together by a process called reeling, which is carried on where the silk is raised. This reeled silk is the "raw silk" of commerce and the raw material of our silk mills.

It is still too fine for weaving, and passes through several processes of doubling and twisting, which convert it into what is called "thrown silk," each operation increasing the size and weight of the yarn. The fact that a fibrous mass like cotton or wool is successively made finer, while silk is made coarser during conversion into yarn, explains why the system of yarn numbering for one is directly opposite to that for the other. When the process makes the strand finer, a fixed weight and a variable length are used; when the strand grows coarser as with silk, a fixed length and a variable weight form the basis. With both systems the number increases as the process of manufacture advances. From this it is easily seen why the "spun silk" yarn, which is made from the tangled mass of waste silk, is numbered by the cotton and not by the silk system.

The Lowell writers state that three different systems are used in America for raw silk. This is a mistake; they confuse raw with thrown silk. The following statement is by a practical silk manufacturer who buys raw silk and converts it into cloth, James Chittick, Clifton Silk Mills, Weehawken, New Jersey:

> Regarding the various systems for denoting the sizes of raw silk, I would say that, while different methods of more or less merit have been proposed and adopted from time to time (the last one, I believe, being arranged at the recent Paris Exposition), yet in this market (New York) at any rate, there is little use in considering anything except the old system based on reelings of 476 metres. This is the only one, practically, in which business is transacted. All the letters and cables from Europe and Asia, all the reports of sales, crops and conditions, all the conditioning houses, every one in fact, uses this system in their talk and in their trading.

This 476 metre or 520 yard basis is simply the metric equivalent of ½ of an ancient French length—9,600 aunes, of which the weight in deniers (an old French coin) indicates the number of the silk yarn.

The French have tried in vain to change this denier-aune standard, until at the Paris Metric Congress of 1900, they acknowledged defeat, abandoned the metric standards which no one would use, and adopted the metric equivalent of the denier—400 aune basis (which is demi-decigramme-450 metres), sugar-coating the dose with the pretence that they thus reached a metric basis. Knowing that the trade would not use the outlandish word "demi-decigramme," they actually abandoned the sacred metric nomenclature and called the demi-decigramme a denier.

A few extracts from the proceedings, showing how the metric system was abandoned by its friends in the place of its birth in 1900, may not come amiss at this point for those who propose that all raw silk coming from foreign parts shall be numbered by the decimal system in America. Bear in mind that the use of 450 metre, Italian system, in place of 1,000 metres is the use of $\frac{9}{20}$ in place of $\frac{1}{10}$ and the complete abandonment of the decimal basis, notwithstanding the statement to the contrary in the Paris resolution which follows. The 450 metres is simply the metric equivalent of an old length originally expressed in aunes.

M. Chamonard, Page 35. Silk. There is, to be sure, considerable apparent confusion in the measures used in the various silk markets. In France, in spite of the law of 1866, the denier (.0531 grams) -.476 meters is used; in Germany, the Turin system denier (.05336 grams) -476 meters; in Italy, the denier (.05 grams) -450 meters. But these local measures which seem very diverse are nearly equivalent. Thus, 20 denier Italian corresponds to 19.80 denier French and to 19.90 denier Turin. Now the new numbers proposed (but not adopted by this Congress) will be 11 per cent. higher; a 20 denier Italian would be 22.20 by the new method.

Lyons stated frankly the terms on which it would "adopt" the metric system in these words:

M. Chamonard, Page 35. The system which these two Lyons Chambers propose is practically the use of a ticket on which the weight in demi-decigramms per 500 meters will be reduced to the local system of each country.

Hear the pathetic appeal of that lost sheep, the waste silk spinner. Page 44:

M. Strohl. I am a spinner of waste silk and I pray that something be done for us. If I go the cotton section, they tell me that my line does not concern them; if I go the wool section which has the metric system, they likewise tell me that I am not in their line, and so I come to you to ask that you support the 1,000 meter-kilogramme for spun silk.

Now come the resolutions by the Paris Metric Congress as to numbering silk. Page 43:

M. Testinoire read the following resolutions:

Whereas: The official French numbering for silk, defined by the law of 1866 has never been used in the silk trade, and,

Whereas: The only systems in use are the Lyons, used in the United States, France and Japan; the Italian used in most of the other silk countries, notably in Germany, Austria, Italy and Switzerland, and,

Whereas: It is important while seeking unification on metric and decimal bases to take into account the customs of the different silk markets, and,

Whereas: The difference between the two above-named systems is negligible, therefore,

Resolved: That the Italian system, which is metric and decimal,* be adopted by all nations as the international standard.

Adopted unanimously.

---

* It is not decimal and no more metric than it is English or Chinese. As well might we convert the 1000 meter-kilogramme into a 495 yard-pound system and call it English.

In other words:

Whereas: Water will not run up hill at our command, therefore,
Resolved: That that water shall in future run down hill.

The light is breaking when a system of weights and measures is adopted at Paris because it is in general use. Fortunate, indeed, would it have been for the unification of the world's weights and measures if this principle had been recognized in Paris 110 year ago by making the French metre 36 inches and the French pound 16 ounces.

In some of our large silk mills when raw silk is converted into woven cloth the denier-aune or its English equivalent is retained until the yarn becomes cloth which is then measured by the yard. With such exceptions the only English standard for thrown silk deserving any attention is based on the weight in drams of 1000 yards. That the dram 1,000 yard base, which is the standard for this country and Great Britain, has invaded even France, is shown by the following extract. Paris Metric Congress. Page 33:

M. Persoz. The English dram system is used also in the Calais district in the machine lace industry.

The two following letters, one from Messrs. Cheney Bros., South Manchester, Conn., the leading silk manufacturers of this country, and the other from Charles H. Knapp, Paterson, N. J., builder of silk reels and scales, show what American silk standards are to-day:

South Manchester, Conn. *January* 27, 1903.

Dear Sir:

Your letter of January 26 is received. The system of numbering silk to which you refer, as using 20,000 yards to an ounce, is one which is unfamiliar to us. We do not remember to have ever seen it. The dram per 1,000 yards system was established in the days before the invention of the Grant Reel, when skeins were generally reeled 1,000 yards in length and the size could be determined by weighing the skein. This is no longer true, since the introduction of the Grant Reel, the skeins being made much larger, but the system is still used to designate thrown silk by a great many manufacturers, chiefly for trams.

The denier system is almost universally used on raw silk. We use it for thrown silk as well, trams and organzines. In thrown silk this system is in quite general use for designating the size of organzine, but very much less frequently for tram. One dram is equivalent to 17 4-10 denier. There is a comparative yarn table which was first published in Scotland a good many years ago and has since been used in most of the books of calculation. It can be found in the pamphlet published by the Silk Conditioning House in New York and also in the Silk Calculator, published by John J. Ruegg, Paterson, N. J.

The 20,000 yard per ounce system is not recognized in these tables.

Yours truly,

(Signed) CHENEY BROS.

PATERSON, N. J., *January* 29, 1903.

Dear Sir:

Yours of the 28th at hand. I do not know of any standards for thrown silk other than the dram 1,000 yards. Thrown silk is bought, sold and talked about as such a dram, "organ" or "tram" silk, the 1,000 yards being always understood.

Very truly yours,

(Signed) CHAS. H. KNAPP.

The ounce-20,000 standard which is bothering the Lowell instructors is not known to these authorities. If we follow Professor Crosby's advice, this dram 1,000 yard standard will be abandoned for a demi-decigramme (denier)-450 metre base, all in the name of simplicity and uniformity. How does he propose to make the change? Why, what the bayonet has failed to do in the mills of France is to be done in our mills by teaching the children in the schools.

Outside of the silk industry, for which a separate system of numbering is required, the Lowell instructors have, by counting one standard (300 yards) twice, succeeded in reaching a total of 8 systems of yarn numbering, which they assert are used in this country. Five of them are credited to the carded woolen branch. Of these five the 20 yard-grain method is not a system of yarn numbering at all. It is one of many methods of weighing used principally in knitting mills where the count of yarn does not play so important a part in technical calculations. Not only the 20 yard length, but also 6¼, 12½, 25, 50 and 100 yards, are used, in fact, any length that suits the weigher. These methods, which are based on a fixed length and variable weight (as for silk), are sometimes used for indicating the size of very coarse yarn and slubbing, for which the ordinary fixed weight and variable length system is unsuitable. These exceptions would occur with the metric or any other system.

By scraping this country and Canada with a fine-toothed comb, other woollen systems than the two first mentioned (300 and 1,600 yards) might be found in isolated weaving mills. I do not say they can be found, for in a continuous service of nearly twenty-five years in manufacturing woollens, only the 1,600 and the Philadelphia 300 yard standard were encountered. The others, if they are to be found on this continent, are of no significance.

The American yarn standards for the weaving industry, exclusive of silk, are four in number, as explained early in this paper. Every one of them, as well as every one of the eight (counting one twice) mentioned by Professor Crosby, is based on the English yard-pound. Assume the existence of these eight, however, square them and multiply the product by 10; scatter the resulting 640 at random through the cotton, woollen, worsted and linen mills of America, and the effect would be simplicity itself compared with the concurrent use of two systems based on incommensurable units such as the yard-pound and the kilogramme-metre, which paralyze calculations with such problems as the conversion of yarn gauged by skeins of 768.09 metres per 453.59 grams into yards and pounds of cloth. Page 543 treats both of yarn numbering and of the law. The theory that the vast and complex industries of the country are to be hypnotized into adopting the metric system by seeing it forced on a few helpless government employes is certainly new. The failure of a century of direct compulsory law in France ought to be a lesson to Americans, for whom the power of law over weights and measures was thus defined by John Quincy Adams:

These purposes, regulation of weights and measures, however, require powers which no legislator has hitherto been found to possess. The power of the legislator is limited by the extent of his territories and the numbers of his people. The principle of universality, therefore, cannot be made by the mere agency of his power, to extend beyond the inhabitants of his own possessions. The power of the legislator is limited over time. He is liable to change his own purposes. He is not infalliable; he is liable to mistake the means of effecting his own objects. He is not immortal; his successor succeeds to his power with different views, different opinions, and perhaps different principles. The legislator has no power over the properties of matter. He cannot give a new constitution to nature. He cannot repeal her law of universal mutability. He cannot square the circle. He cannot reduce extension and gravity to one common measure. He cannot divide or multiply the parts of the surface, the cube or the sphere, by the uniform and exclusive number ten. The power of the legislator is limited over the will and actions of his subjects. His conflict with them is desperate, when he counteracts their settled habits, their established usages, their domestic and individual economy, their ignorance, their prejudices and their wants; all which is unavoidable in the attempt radically to change or to originate, a totally new system of weights and measures.

At the metric hearing the Congressional Committee were duly impressed with the following testimony of Professor Crosby:

If it is of interest to you I can exhibit the details of a problem in cloth analysis, done both by the ordinary and by the metric systems. In the case of the former several sheets of paper are required to contain the figures, while in the metric system but few figures are necessary. . . . One afternoon I asked him (my head instructor) to make me sample calculations both on the metric and the American systems. Without any special preparation, other than ascertaining the constant relation between metre and yard, pound and kilogram, he returned to me in the morning these calculations to which I have referred.

The Chairman.—Have you got that work here?

Professor Crosby.—I have it in my notes and shall be glad to put it on record if you wish. The ease and rapidity of calculation as compared with the present system in actual use is greater than any of us had thought for. I can furnish many other illustrations, if desired, along this same line.

The promised figures were not included in the report of the hearing. Every effort to secure a copy of them failed, although the friends of the metric system were exultingly pointing to this testimony as proof that the metric system would be a great aid to the textile industries.

An experience of nearly twenty-five years in textile mills has shown that calculations by the English system for cloth analysis, carried no matter how far, do not necessitate filling several sheets of paper of ordinary size with figures, and to demonstrate that fact the method used continuously for years was illustrated by practical examples in "Is It Worth While?" and "English versus Metric."

In the Lowell example the first thing that meets the eye is the loom width of the goods; English, 31½ inches; metric, 8 decimetres. It may be well to explain that cloth is made wider in the loom than when finished, to allow for the shrinkage in finishing, the difference varying widely with different fabrics. This loom width must be adjusted with extreme care that not only the final width, but also the weight, "handle" and finish of the goods may be right. A difference of an inch in the loom width may mean the difference between the success and failure of the fabric. I remember a case where marking the loom width $3\frac{4}{10}$ inches more than it should have been, by a designer in copying a draft sent to a branch mill, filled that mill with tender and unmerchantable goods.

The practice in mills is to express loom widths in tenths of an inch by the English, and in centimetres by the metric system.

One of the defects of the metric system in textile manufacturing is found here. The centimetre ($\frac{4}{10}$ inch) is too large for the unit of width. The millimetre is too small, and necesitates the use of four figures to express the widths of most cloths. The tenth of an English inch is the ideal unit for this purpose. The expression of the width in even units, each four inches long (decimetres) in the Lowell example, stamps the Lowell fabric as supposititious, designed to serve the purposes of the comparison. The centimetre is too large to express the loom width; the decimetre for this purpose is simply impossible.

The next feature to arrest the attention is the extension of the weight per yard to the ten thousandth of an ounce. The weight per yard of such goods as the Lowell fabric is supposed to be is expressed in tenths of an ounce. It is usual to allow for an unavoidable fluctuation of at least one-half ounce per yard in the pieces as they come from the mill, yet in the Lowell English lay-out a difference of less than $\frac{1}{20}$ of a grain per yard is calculated. The practical character of the Lowell example can be judged from the fact that it would require 160,000 yards, or over 90 miles of cloth to make this difference equal a pound. Remember that this fabric is offered as an example of metric consistency.

Turning to the metric lay-out, we find the weight per metre expressed in hundredths of a gram (about $\frac{1}{7}$ of a grain). From a practical point of view $\frac{1}{7}$ of a grain per yard of cloth is just as preposterous as $\frac{1}{20}$. The two may be likened to indicating the distance between Lowell and Boston in millimetres and in centimetres. The ideal unit with which to express the weight per yard of cloth is the English ounce divided into tenths, *and there is no metric unit that even approximately corresponds to it.* The gram ($\frac{1}{28}$ of an ounce) is too small; the dekagram ($\frac{1}{3}$ of an ounce) is too large.

In the form in which the problems appear in the Lowell paper no opportunity is given to compare the different methods of calculations, in fact, one looks about as complicated as the other. I, therefore, annex these Lowell problems worked out in full by three methods, Lowell English, Lowell metric, and my own mill practice. In the last-named, no other principles have been applied than those explained in this paper. The calculations tell the following story:

Mill English requires 160 figures.
Lowell metric requires 245 figures.
Lowell English requires 223 figures.

Of the metric figures, 90 are used for the final reduction, so that the metric alone would require 155 figures.

The metric system in the Lowell Textile School has enabled the student to accomplish with 245 figures what he could do with 160 by the mill English method, or with 223 figures even by the very elementary formulas of the Lowell English calculations.

These comparative tests of the English and the metric systems, like the problems in cloth analysis in "English versus Metric," show that textile calculations can be made more easily with the English than with the metric system. They show that the sizes of the English units are well suited for the practical requirements of textile measurements. They also show that neither the metric

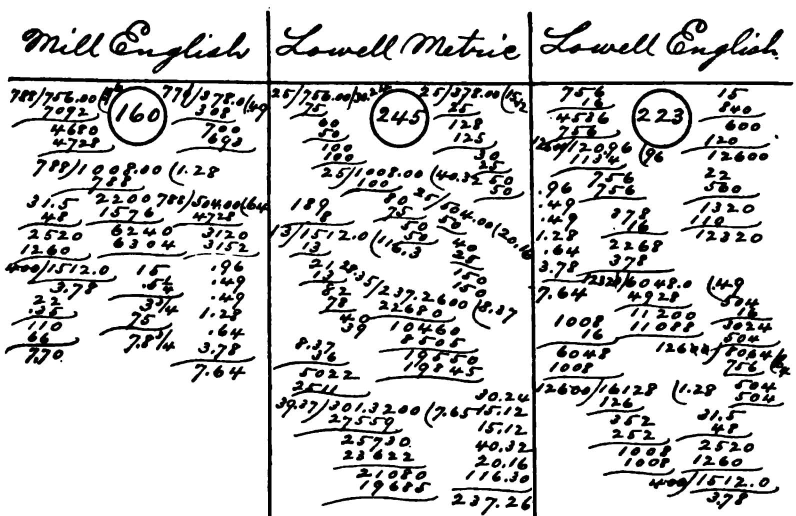


FIG. 115.

linear, surface nor weight units are suited for such measurements, being invariably either too large or too small for the purpose.

Why should an approximation of the ten-millionth part of the distance from the equator to the North Pole via Paris, successively multiplied and divided by ten, give units suited for the manufacture of textile fibres into yarn and cloth for covering the nakedness, or protecting, or adorning the body of man?

The claims of superiority for the metric system in textile manufacturing consist entirely of generalizations. Subjected to a practical test, based as in "English versus Metric," on a sample of cloth found in the market, the metric is found to be decidedly inferior to the English system. If the comparison is made, as in the Lowell case, under imaginary conditions favoring the metric, the superiority of the English system becomes even more manifest. If practical mill men have, as Professor Crosby asserts, demonstrated the superiority of the metric system, the public has not yet been let into the secret. As to juggling with figures, the record speaks for itself.

What, then, is gained by the use of this metric method? Nothing. What is lost in addition to time and labor? A great deal, not the least being the loss of practice by the student in making English calculations which he must use in the mill. Another thing that is lost is the clear idea of the relations of raw materials and finished fabrics to the size numbers of the yarn.

It should be carefully borne in mind that these calculations do not show the chaos that results from the use of the two systems, English and metric, in the same mill, with the constant oscillation between incommensurable units. With the exception of the final conversion in the metric process these calculations are either English or metric. The chaos, or, as Herr Muench-Ferber expresses it, the "ungodly disorder" which is caused by the use of both the yard-pound and the kilogramme-metre in mill work, is faintly shown by Frowein's estimate of cost in "English versus Metric," and still better by French and German technical books and journals.

Following the calculations comes a reference to a Bradford conditioning house. A conditioning house is not a mill. In it not one of the processes by which raw material is converted into cloth is carried on. The material is received and delivered, certificates being issued as to its condition. It is a storehouse in which the employes deal with textile fibres in a state of rest. They do not come in contact with the problems of the mill as does the manufacturer. Their point of view is limited. They are not in a position to fully recognize the needs of a mill or the danger of interfering with mill methods. For their calculations, thus restricted, an exclusive decimal system is sufficient, as it is for bookkeeping, and the managers of conditioning houses are disposed to favor an exclusively decimal system of weights and measures for the same reason that influences men whose minds are occupied exclusively with accounts. Decimals alone serve their purposes, and they think it is the same with everyone else.

This phase of the question was well illustrated by the 171 Chambers of Commerce throughout the British Empire, which declared for the metric system. This threw the Paris Metric Congress into convulsions of joy, on which the English delegate, Mr. Crawford, poured cold water in these words. Page 60:

M. le president. Cannot the 171 Chambers of Commerce do anything?

M. Crawford (English delegate). We have brought the subject to the attention of the Chancellor of the Exchequer, but he replied that the 171 Chambers of Commerce do not represent the country.

One solitary mill, making cotton warp and shoddy filling goods in Batley by the metric system, would be entitled to more weight in this discussion than all the conditioning houses in Europe.

While the manager of the Bradford conditioning house is pegging away on the metric system with a tack hammer, the growth of the only three great undeveloped nations of the world, America, Russia and Great Britain, is driving English units into every part of the world with a pile-driver.

The next thing touched upon is the report of the yarn trade of India. It is by no means a new story, having been circulated freely during the past year by advocates of the metric system in all parts of the world. In substance, the claim is that the users of silk and woollen yarn in India have become so accustomed to the metric system of numbering yarn that they will have no other, especially in the "up country," and that the Indian government has approved of the importation of such yarns by reason of the demand.

Before addressing ourselves to silk and woollen yarn in India it is well to state that the hot climate of that region makes cotton and silk the principal materials for clothing there. Except in the hills, wool is used to but a slight extent. India is both a cotton-growing and a cotton-manufacturing country. Here are operated 5,000,000 spindles, producing cotton yarn and cloth from the cheap cotton with the cheap Indian labor, at a cost that has driven even the English-made yarn from the Chinese markets. Every pound of this yarn is spun by the English system of weights and measures.

Another fact to be kept in view is that every proposition to introduce the metric system into the British Empire has contained an exception as to India. One reference on this point. Paris Metric Yarn Congress. Page 69:

M. F. Roy. The English Chambers of Commerce that ask for the metric system in England make an exception of India, where they declare it is impossible to change local habits without great disturbance.

The inertia of 300 millions of Asiatics split up into castes and accustomed to their own and the English weights and measures, is too much even for the decimal enthusiasm of 171 Chambers of Commerce. The Sepoy Rebellion is not yet forgotten.

We can dismiss that part of the Indian story relating to silk yarn. The metric system is not used for silk, even in France. We have already seen how the Metric Congress at Paris adopted a silk system, partly because it is used in the United States.

This narrows the issue down to woollen yarn in India. An examination of the Official Annual Statement of the Trade of British India with Foreign Countries for the year ending March 31, 1900, fails to disclose a rupee's worth of woollen yarn imported into India. A statement of imports of all kinds into India for the seven months ending October, 1901, likewise contains no record of any woollen yarn. There were large quantities of cotton yarn and cloth, raw silk and silk goods, woollen piece goods and shawls, but no woollen yarn. With the desire to run the story down if possible, the files of the *Indian Textile Journal* were searched, and under the date of September 15, 1902, the following item appeared:

It may be noted that at Karachi, last year, the Collector of Customs reported some consignments of yarn imported were marked the same way as English yarn, but differed materially from the English standard. The importers alleged that the yarn was spun and marked according to the metric system of counts.

The importers "alleged" it was metric, but was it the metric or some of the 28 different European systems of numbering yarn that were used for this jag of yarn unearthed by a customs collector at the mouth of the Indus in 1901?

There are a number of errors in the letters from which Professor Crosby quotes. Mr. Wolmer's statement about "preference" for metric woollen, worsted and silk yarns cannot be true as to silk, and is contradicted by an observer in India as to woollen and worsted. The following letter is from a man on the spot, who quotes from the official record, and ought to know the facts:

BOMBAY, *November* 8, 1902.

To the Editor of Textile World, Boston, Mass.

Dear Sir:

Referring to your inquiry of the 6th of September, the Government of India have now no objection to the application of the metric system of marking to both silk and woollen yarns, "provided that the manufacturers follow the metric system in full, qualifying the marks with the words 'Continental' or 'Metric system of counts' and give the country of the origin of the yarns; and provided also, that the yarns marked in acccordance with the British system are admitted freely as heretofore." The system itself has not yet made any headway here, nevertheless, and merchants think it will take some time before it is fully introduced into this country. Government, of course, will not undertake to specify particular weights and measures until experience shows what is best to adopt for the country and much also will depend on the adoption of the system in England and Germany.

Yours truly,

(Signed) S. M. RUTNAGUR,

Managing Editor of Indian Textile Journal.

Such testimony should give this Indian story of woollen and silk yarn its quietus. Before dismissing the subject, let me call attention to the statement of McDonald & Co., of Karachi, India, that the system in vogue on the Continent of Europe (which one is not stated) suits the Indian looms better than the English system does. There is not the slightest adjustment of a loom that is in any way affected by the particular system used for numbering yarn. Metric reeds would be required if the metric system was used for the cloth (length and width) as well as for the yarn, which is surely not the case in India. But a change of any part of a loom to suit a system of yarn numbering? Never.

The cry for the metric system to help our foreign trade is next made. A single fact is sufficient to prove how fallacious this appeal is. England to-day dominates the textile export trade of the world, with goods made and sold by English units. Her exports of textiles, added to those from India and the United States, all made by English standards, amount to $425,000,000 per year, as compared with $95,000,000 exported from the so-called metric countries, France and Germany, and made only partially to metric standards. In our leading foreign market, China, the import duties on textiles are levied by English units. The new Chinese tariff has within two months been published in German papers for the benefit of the German exporters, and not a single reference is made in it to the metric system. The list covered fifty-three items. The rate for three of them was based on the Chinese "catty" (1⅓ lbs.); for five, the rate was ad valorem; while on all the other forty-five the duty was levied by the English yard, inch or pound.

If a foreign customer wants goods billed in any special units, it can be done by a simple process of conversion, which does not interfere with manufacturing processes. Following are a few extracts from the proceedings of the Paris Metric Yarn Congress, bearing on this point. Page 69:

M. F. Roy. In certain of our French colonies the metric system has not been introduced. It is necessary to proceed gradually and at first to mark the number of metres beside the yards and the metric beside the English numbers.

Baron Esnault-Pelterie. This difficulty (in foreign trade) has been solved in France, since we export to the far east our cloths folded by the yard, although the metric is the legal system in France.

Professor Crosby himself unconsciously gives an object lesson in conversion in his metric calculations.

The claim that adopting the metric system would help us to sell yarn abroad is grotesque in face of the fact that Germany has been forced to adopt the English standard for levying duties on yarn because German manufacturers use that standard. The yarn exporting nations are laboring under no such delusions. Here are a few extracts from statements made at the Paris Metric Yarn Congress of 1900:

M. Baron Cantoni, Italy. The Italian government is at all times favorable to the use of the metric system in numbering yarn, and I doubt not it would accept immediately the new numbers for statistics and tariffs. As a matter of fact, we find ourselves in the strange situation that all of our commerce is based on the English system of numbering while the government has adopted the metric system. After preceding yarn congresses, we have tried to introduce the metric system without a compulsory law, but individual action was not sufficient. There are difficulties in the way of a compulsory law; for some time past, Italy has been an exporting country. An importing country may oblige the foreign exporters to conform to its regulations. But with an exporting nation the affair is more difficult. Italy has no colonies. We export about 60 million (sic) of cotton yarn and cloth to foreign countries and we compete directly with England, and until England changes we cannot hope to introduce a new system in the Orient or in other markets.

It is necessary to remember that nearly all the exports of cotton yarn are from England, and we can do nothing if that country does not adopt the system we favor. . . . . The difficulty will always be in exporting to uncivilized lands where the people have been accustomed for a hundred years to English measures and numbers and where articles of cotton are often used as currency.

Everything depends on England. Our silk weavers, who are the only manufacturers importing combed cotton yarn in fine numbers, find these yarns in stock in Manchester to supply their wants; they would protest against this burden (changing to the metric system.)

M. de Pacher. To begin with, I must say that it is my belief that uniform numbering can be obtained in all countries only by a law made compulsory after a certain date. The spinners who should begin to number their yarn according to the resolutions of this Congress before the old numbers were prohibited by law, would be under the necessity of keeping their product until forced to sell it at the best price and an incalculable loss.

We have followed Professor Crosby to the end of his paper, and considered his arguments as well as their general character permits. In the textile world the metric system has no reason for its existence. There are three objections to that system, any one of which would warrant its rejection as a candidate for international favor:

1. The size of its units are not suited to mill work.
2. They are incommensurable with those of every other system on earth, which makes their use with other units a practical impossibility.
3. The system is used to but a very slight extent, its partial introduction in Continental Europe having served only to make a bad matter worse.

On the other hand, the English system is a real international system, used for probably three-quarters of the textile work of the world to-day. Its units, commensurable with the linear units of the Russian Empire, are certain to become the system for the undeveloped portions of the earth, America, Asia, Africa and Australia. Finally, these English units, the result of the industrial evolution of untold ages, are exceptionally well suited to mill work.

There is one thing more to be taken into consideration—the impossibility of our changing the existing standards, even if it were worth while. History furnishes no record of a language or a system of weights and measures obliterated by arbitrary power. Every attempt of the kind has only emphasized the weakness of man's brief authority. The use of languages, weights and measures has been extended and restricted only by the rise and fall of empires and peoples, subject to a higher law, which sets congresses, parliaments, kaisers, presidents, emperors and czars at defiance. Even when languages and systems of weights and measures have apparently disappeared, traces of them, like the fossils in the rocks, can still be found in the succeeding languages, weights and measures of the world, to show that the units of a dead past form the structure of the living present.

With these conditions so plain, one cannot restrain a feeling of admiration for the jaunty way in which Professor Crosby starts out to "change everything." "It is magnificent, but it is not war." Instinctively it recalls Don Quixote's famous attack on the windmills, and I cannot refrain from addressing to the professor the words of Sancho Panza to his master as the latter was about to charge:

"Look, sir, those which appear yonder are not giants but windmills; and what seem to be arms are the sails, which, whirled about by the wind, make the millstone go."

Mr. Paul Lamoitier, of Moscow (by invitation).—I wish to thank the American Society of Mechanical Engineers for sending me the paper by Mr. Halsey, and I desire to avail myself of the opportunity to correct certain of his statements. He says: "The only effect of the adoption of the metric system in both of these countries, has been to add a new set of units to the old ones." On the contrary this has had effects quite different. 1. The metric numbering of yarns replaces, little by little, the former abitrary calculations. 2. It is actually the system most in use in Europe. 3. In a few years there will be no mention made of the different standards of Saxony, Austria, Prussia, Sedan, Elbœuf, Roubaix, Reims, etc. The questions arising from these units are of less and less consequence all the while.

It appears to me, on the other hand, that it should be stated moreover that the campaign in favor of the universal adoption of the metric system in numbering yarns only dates from a few years back, and that this period has been sufficient to render this adoption complete in a considerable number of establishments. The French numbering for cotton is based on the metric system, the standard being 1,000 meters and the unit of weight 500 grams. It is desirable that the unit of weight should be 1,000 grams, as I have stated in the article to which you refer. If this were done there would be only a single unit for all textile material.

I wish the American Engineers could visit Europe (exclusive of England), and through all the industrial cities which spin or weave cotton and wool would ask the following questions: 1. Do you use the metric system in your calculations and in the numbering of yarns? 2. How do you find it in practice?

I feel in a position to answer in advance that the adoption of the metric system would impose itself on the United States as it has already imposed itself on the textile industry in Europe. I have said that it was absurd, moreover, to use in this industry any other units in those countries where the metric system is legalized. I repeat it. The most difficult thing to overcome in this matter is conservatism and ignorance, but progress will remove both of these.

The adoption of the metric system does not complicate calculations; on the contrary it simplifies them if one's judgment is based on a broad view and not on special cases. In England the opposition comes principally from an opinion that the commerce based on the texiles would suffer when it changed. This is an error. In the first place, to allow competition in the markets nothing would prevent the competing nations from using occasionally the English names. This is what Germany does. Besides, I will cite a personal example to show that this contention is not justified. In the shop of Messrs. M—— we use cotton, woolen, worsted and linen yarn, spun silk and organzine, which are the principal textile materials sent to us from France, Germany, England and Russia. About 80 per cent. of this yarn is numbered in accordance with the metric system. Only the threads of silk and the English yarns have a numbering which is distinct, and this would be a reason for buying less of them, since these arbitrary numberings disturb our calculation.

Furthermore, even if certain nations would like to change (which is in no sense the case), they would go back by preference to their old system rather than the English system, which has survived like the rest. As the result of this, it is difficult to understand the obstructive attitude of certain persons in the United States. It is certainly the case that the classes in France which are less instructed have not spontaneously adopted tne metric system. But there are fewer reasons than there were sixty years ago for not adopting a system which has been approved in the entire world, and which is official in a number of countries.

All praise, then, to the United States, which is sure to show itself a true leader of progress, if they admit irrevocably the introduction of the metric system for all their calculations. The one thing necessary is not to have any longer two weights and two measures. This is the sole reason for the chaos which is so much dreaded. When they will count their numbers of threads by the number of kilometers of thread in a kilogram (a measure having the same root as the metre): when they will count their silk no longer in deniers of Montpellier, Lyons, Milan, or Turin; when they will speak no longer of silk as of 8–10 denier, but of the unit in its relation to a thousand, so as to measure a thousand times a thousand meters per kilogramme, the textile world will have a simple, comprehensible, fair and workable system.

It is to be hoped that at the Exposition in St. Louis, there should be a congress held on this subject, in order to arrive at a universal understanding for the general adoption of the metric system, on the one hand, and upon the other of a compulsory measure for the adoption of a method of numbering threads which should be the same for all textile materials, the unit of weight being the kilogram, and the designation being expressed by the number of kilometers contained in the kilogram of weight.

Mr. F. A. Halsey.—The following reply to M. Lamoitier, like that to Professor Crosby, has been prepared by Mr. S. S. Dale.

Previous to addressing this Society, M. Lamoitier in his book and in the columns of *l'Industrie Textile*, Paris, has been a valuable contributor to the metric discussion. In both of these publications he addressed his fellow-countrymen—in his book to instruct them in the technical processes and calculations of textile manufacturing; in his journal to reproach them for their neglect of the metric system and to arouse French public opinion in favor of one more metric law.

One was the calm, exact, carefully measured words of the technical expert giving all the known facts bearing on the subject; the other the impassioned outburst of a Frenchman who has seen his own writings quoted in America to prove that the French textile manufacturers themselves did not use the metric system in their mills. These, his earlier writings, are a conclusive reply to his latest statements to this Society. A comparison of the two shows how difficult it is to call for more law in France to make Frenchmen use the metric system, and at the same time urge Americans to adopt the metric system because Frenchmen are using it.

M. Lamoitier's first declaration is that the metric system of numbering displaces "little by little" the old and arbitrary calculations. Even if this were a fact, his case depends upon what he means by "little by little." The difficulty of introducing a new system of weights and measures and displacing an old one — in other words, the length of the "transition" period—is one of the strongest objections to any attempt at making a change. The following extract from the proceedings of the Paris Metric Yarn Congress of 1900 shows how this "little by little" affected the veteran M. de Pacher, who was Secretary of the Congress of 1873 and presiding officer of the Brussels, Turin and first Paris Congresses, as well as of the one at which these words were spoken (page 20):

M. de Pacher.—The efforts of a quarter of a century have had such slight results that my feelings are in truth touched that you should recall my name after so many years.

The next statement is that the metric system is the one most employed in Europe. This is contradicted by every unbiased French and German textile writer on the subject, by the evidence of French and German journals, by the German Reichstag, which levies duties on yarn by the English system, by Herr Muench-Ferber, quoted in Mr. Halsey's paper, and who is a delegate to the Reichstag and a textile manufacturer, and last, but in the present discussion by no means least, by M. Lamoitier himself.

The facts as learned from the above authorities are these:

In the linen, jute and flax industry the English system, with the exception of a local and unimportant Austrian standard which is not metric, is supreme. I will quote a few authorities:

M. Lamoitier in his book, page 63:

The English system is used for the linen, hemp and jute.

At the International Congress for Yarn Numbering at the Paris Exposition in 1900, M. Boucher-Feyerick, delegate from Belgium and a linen spinner, stated in the following words why the metric system had made no progress in the linen and allied industries (page 60):

We Belgians export enormous quantities to England, Asia and Egypt, and we cannot adopt the metric system without risking the loss of this trade. Our customers in the countries named are familiar with the English system of numbering, and if we do not give it to them, our competitors will, and we will lose the market. I speak not alone for myself, but for all Belgian spinners. We cannot change.

That the English system is the principal one in use in the cotton industry is not disputed, although the metricists try to ignore the fact. The metric standard, 1,000 meters per kilogramme, is used but little. The French use a system based on the French pound. In their attempts to get other nations to adopt the metric system the metric theorists promise that the present French cotton system will be abandoned. But will it? Where is the power to compel such action on the part of the many individuals engaged in the French cotton industry?

In *Kalkulator* fuer "Artikel der Textil-Industrie," Fritz Frowein says (page 82):

> While the acceptance of the metric system in yarn numbering is advocated in some quarters of the industry and by theorists, the author (Frowein) does not believe in its practicability. On one hand, the cost of changing machinery, and on the other hand the change of size numbers place unsurmountable difficulties in the way.

In the *Leipziger Monatschrift fuer Textil-Industrie* of October 31, 1902, is an article on waste and take-up in cotton weaving. An elaborate table gives the amount of waste and per cent. of take-up with each size of yarn for fabrics of different sets (threads per inch). The sizes of the yarn are given in English counts; the set is given in threads per Vienna inch; the weight of the waste is given in English pounds. Such is the condition that has forced imperial Germany to levy duties on cotton yarn by the hated English yard-pound.

In the European silk industry, which is centered in France, the metric system has made but little impression during the 100 years of its existence. Reference is made to M. Lamoitier's *l'Industrie Textile* article in the October issue of the *Textile World* and to the statements at the Paris Metric Congress, quoted in the reply to Professor Crosby.

We next come to the woollen and worsted industries. Here again, fortunately, we have evidence from Continental Europe, including that of M. Lamoitier himself, to guide us:

"Traite de Tissage," by Paul Lamoitier (page 87). See Mr. Halsey's paper.

Paris Metric Yarn Congress of 1900, page 87:

M. de Cheville.—We hope no new burdens will be imposed on the industry, but if we look the facts in the face, we will find that notwithstanding the decree of 1810, and in spite of the serious efforts put forth by industrial societies of many districts, we still have the ancient units of weights and measures and we scarcely comprehend each other when we talk spinning at Reims, Roubaix, Elboeuf, Sedan or Vienna, where the skeins still measure 1420, 710, 3,600 or 1,500 meters.

The next statement that "in a few years there will be no mention made of the different standards of Saxony, Austria, Prussia, Sedan, Elbœuf, Roubaix, Reims, etc.," is merely a prophecy not supported by the experience of the past, and which time alone can verify or disprove. It is in line with the optimistic views of the French people regarding the metric system since its foundation 110 years ago, and which are still far from realization.

His statement that "the campaign in favor of the universal adoption of the metric system in yarn numbering only dates from a few years back" shows how the decimal delusion blinds its victims to the facts of history. Here are a few articles from an imperial decree of Bonaparte in 1810, still in force except for cotton:

Art. 1. On and after March 1, 1811, all proprietors of spinning mills shall make the hanks of cotton, linen, hemp or wool, each 100 meters long, so that a skein shall measure 1,000 meters in length.

Art. 2. These yarns shall be ticketed with the number of such skeins in one kilogram.

Art. 3. Violations of the foregoing provisions shall be considered breaches of the police regulations and punished by a fine of not less than 5 nor more than 15 francs for the first offense; the fine may be increased for a repetition of the offense.

This old statute proves that the application of the metric system to the textile industry has been one of the settled purposes of the French government. What is the result? M. Lamoitier himself gave us the answer in *l'Industrie Textile* for October 15, 1902:

We (the French) are as much in the anarchy of weights and measures for the textile industry as at the time of the Revolution.

Such drastic laws as that above mentioned would not be tolerated for an instant in America. Just imagine the cry of "Police!" on Leonard Street, New York, because some one had found a skein of cotton yarn measuring 840 yards.

It is practically impossible to change the ideas of textile manufacturers regarding yarn numbers. The operatives and managers become thoroughly accustomed to the size numbers by the old system. These numbers become imbedded in every process from the first manipulation of the raw material until the finished product is ready for sale. Along comes a compulsory law which says these operatives must measure everything by the metric system. The result is not the use of the decimal system of yarn numbering. The old numbers are retained from necessity, but the standards on which they are based are, as far as incommensurable units allow, converted into metric equivalents and expressed in numbers which are extremely difficult to handle in calculations.

This has been the experience of Europe; it would be the same here. This is what explains the existence to-day of the 28 different systems of yarn numbering in Europe. We will give a few examples of European yarn standards to illustrate this tendency:

Austrian for flax, length 280.51 meters, weight 453.59 grams; Austrian for cotton, length 1159.5 meters, weight 560 grams; Netherlands for cotton, length 768.096 meters, weight 500 grams; Alsace for worsted, length 750 meters, weight 467.71 grams.

These expressions in metric units are obtained from lengths expressed in old units, such as the Vienna ell, English yard, German pound, English pound, etc. They have been made but partially metric by compulsory laws which have failed entirely to make them decimal. The silk industry supplies a good illustration. The old standard was the denier and 400 aunes. The introduction of the metric system has changed 400 aunes to 476 meters, and made calculations much more difficult. That is all. This conversion process is one of the many serious objections to a disturbance of textile weights and measures. The industry is so complex and the ideas of the employés as to weights and measures are so important to success in manufacturing, that the first introduction of metric units, slow and difficult as it is, is but the precursor of other "introductions" as slow and difficult as the first.

This conversion process has been the rule in all parts of Continental Europe. In the Netherlands an attempt has been made to retain the old expressions of length and weight; the result is a straddle of both the English and the metric systems. The yarn number is there based upon the number of skeins of 840 yards in 500 grams. Words fail in attempting to express the chaos of calculations resulting from such a combination of units incommensurable with the meter and the pound. Such chaos is the inevitable consequence of trying to inject a foreign system of weights and measures into a country having its own units firmly established.

M. Lamoitier's words, "It is desirable that the unit of weight should be 1,000 grams," and "If this were done there would be only a single unit," merely expresses the desire of European textile manufacturers to escape from the dreadful confusion in which they are now involved. They think a way of escape for them lies in getting the Anglo-Saxon race to involve itself in a like chaos by abandoning its present system for the metric, a result that the Europeans view with entire complacency. It may be desirable for them, but is it worth while for us?

He expresses the desire that the American engineers might visit the cotton and woollen mills on the Continent and ask these two questions:

Do you use the metric system in your calculations and in the numbering of yarn?

How do you find it in practice?

He volunteers what he styles an answer to these questions, which is, in fact, a rambling evasion of both of them, an implied confession that the textile industry there does not use the metric system, a vague reference to his having called the metric mix-up absurd and the admission that there are difficulties, which he calls conservatism and ignorance, in the way.

These two questions must not be thus dodged. The first is answered by M. Lamoitier (October, 1902, *l'Industrie Textile*):

> After having established the metric system, is it not truly ridiculous that more than 110 years later we should be still using the English yard, the old or French pound, the denier of Montpellier and Milan, the ancient aune, the many different skeins, etc.?

The second question is also answered by M. Lamoitier as follows (same):

> And this is why they are mocking us when they say we do not use the metric system for numbering yarn and for weaving calculations. Nothing is more arbitrary than to reckon the yarn by the thousand meters and the width of the cloth and the picks of the filling by the inch. It is nonsense and a derision.

Both of these extracts were written for French and not American consumption.

His invitation to visit Europe and ask these two questions recalls the fact that one American engineer, Professor Crosby, did visit the Continent in the summer of 1901; he told the Committee on Coinage, Weights and Measures at the hearing on the metric system, of what met his gaze in a weave room in Switzerland:

> We are already building machinery which excites the admiration of the whole world, and are shipping it to the four corners of the earth. During the summer I visited a large silk mill in Zurich, Switzerland. As the superintendent, who was showing me about, opened the door into one weave room where he told me some of their highest grade and best goods were woven, he smiled and called my attention to the looms, which I found were made by the Crompton & Knowles Company, in Worcester, Massachusetts. It seemed like sending coals to Newcastle. They did not put in these looms as a matter of sentiment, but because of their usefulness.

The fact that these looms were built to English measurements does not interfere in the slightest degree with their use in so-called metric Europe.

The managers of the Zurich mill informed him of the many diverse standards of textile weights and measures in Europe, and said they frequently declined orders that were not expressed in their own units on account of the complications that would be caused in their mill. Here is a Swiss mill, equipped with American machinery, but with its operations handicapped by the European chaos of weights and measures. Cannot Americans heed the warning or must the same chaos be transferred to American looms on this side of the Atlantic?

M. Lamoitier's next statement that the adoption of the metric system (which for America means the joint use of incommensurable units) does not complicate calculations, is not only refuted by his own words already quoted, but is so contrary to reason as to need no reply.

He next falls into a reverie, and dreams of a metric era when the rival nations of the earth shall permit English weights and measures to be used *occasionally*, in order that England and America may sell their goods in foreign markets. He omits to state whether the English and American flags are to be permitted on the high seas then, and whether the Mississippi River is to be the dividing line between a German and a French province.

While doubting the value of the prophecy, we might still appreciate the good faith of the prophet if he had not already placed himself on record on this very point, in *l'Industrie Textile*, October, 1902:

It is a duty and would be a glory to our Government (France) to decree a unification of yarn numbering, the unit of length being the kilogrammeter (1,000 grams and 1,000 meters.) O! no need of a long statute. Two articles:

Art. 1. Textile materials shall be numbered by the number of thousand meters in a kilogram.

Art. 2. All other systems of yarn numbering are forbidden on French territory. The advantages? It would put a stop to the chaos which the Americans ridicule. As for the recalcitrants (English, Americans and others) a very simple procedure will be to oblige them in all countries where the metric system is legal, to mark their yarns by the metric system.

Let us say to them: Do you want to trade with us? Then confine yourselves to that which is the most simple and the most practical.

A large saving in this way will be made in the cost of collecting customs duties in the metric countries. There is no better way than this to make them repentant.

M. Lamoitier cites a single mill, that of M. Michailoff & fils, Moscow, Russia, of which he himself is the manager, and states that 80 per cent. of the yarn he buys abroad is numbered by the metric system. This statement of the case leaves much to be desired. How much yarn does he import? Is the yarn he calls metric numbered by the real metric system (1,000 meters per kilogramme), or by old systems converted into metric equivalents which are not decimal and which are metric only in name?

We know that for cotton, silk, and linen yarn the metric system (1,000 meters per kilogram) is used in Europe practically not at all. Under no circumstances could the textile weights and measures of Europe be fairly judged by the amount of metric yarn imported into a single Russian mill, of which so enthusiastic a champion of the metric system as M. Lamoitier is the manager.

What, however, is the practical result of using the metric system in Russian mills? Two hundred years ago Peter the Great left his throne in Moscow, where M. Lamoitier is now manufacturing cloth, to travel through Europe *incog.* He visited Holland and England, and worked as an ordinary carpenter in the shipyards of those two countries. Impressed with the superior skill and system of the English workmen, he took back with him to Russia four mast-makers, four boat-builders, two sail-makers and about twenty other workmen, to teach their trades to his people. These humble workmen, whose names are now unknown to fame, carried into the industrial system of Russia the English inch. The seed thus planted, has grown silently for two centuries, until to-day the ideas of Russians regarding linear measurements are inseparably bound to that inch or to units commensurable with it. The Russian duim and our inch are the same; an archin is 28 inches; a sagen is 84 inches, or 7 English feet; a verschok is 1¾ inches; a verst, 3,500 English feet.

Somewhat more than one hundred years ago, on the eve of the Revolution, the rulers of France conceived the idea of establishing a universal system of weights and measures for the world. They deemed it fitting that such a system should be based on no other dimension than that of the world itself, the largest and most invariable body that could be reached by man. Scientists were commissioned to measure the distance from the equator to the pole. The earth was searched for an unchangeable metal with which to preserve the prototype of the universal system which was to be like no other ever used by man. The divisions of its units were to be decimal alone, and not left to blind and unreasoning chance. The glorious work was to be a benefit to countless generations of men, and shed undying glory on France. The conception was grand, but in its execution the rulers of France came in contact with nature itself. Man was not yet wise enough to measure the earth. Nowhere could an unchangeable metal be found to preserve the prototype. The ratio between gravity and extension could not be expressed. Only one of the objects was attained; the metric units were incommensurable with every other unit on earth. The result was the deposit in Paris of a metal prototype for this system, no more and no less arbitrary than any other standard of measures has ever been.

To-day, when metric yarn is brought into the Moscow mill, linear units of the system founded by French savants one hundred years ago are placed side by side with the units carried to Russia by the humble English carpenters two centuries ago. M. Lamoitier has just told us of the result of such contact, and adds, *l'Industrie Textile*, October 15, 1902:

It is nonsense and a derision. Note also that while I speak here only of France I could say as much of all Europe. For example, do you know that the Russian reckons the width of his cloth in verschki, the picks by the quarter inch and the yarn by either the French or the English system? One verschok equals one-sixteenth of an archin.

The metric and the English systems are incommensurable, and therefore irreconcilable. The English carpenters brought to

Russia by Peter the Great made Russian and English linear units the same, or commensurable, and thus without intending it, contributed immensely to the unification of the world's weights and measures.

The French, by making their metric units incommensurable with all others, worked in a distinctly opposite direction, and reduced greatly, if they did not destroy, the chances for unifying international weights and measures.

Has M. Lamoitier lost sight of the only remedy for his trouble, the use of the English yarn counts with the English-Russian inch? Cannot our own textile manufacturers see in this Moscow mill the chaos that the metric system would surely bring to American mills? Or must they have their own bitter experience?

The statement that a (metric) nation wanting to change would return to its old and not to the English units means nothing. From it one would infer that the writer had the idea a people can change its weights and measures as easily as it can change its tariff, or even as a man can change his coat. He loses sight of the fact that weights and measures are as firmly imbedded in the national life as language itself.

It may make it easier for M. Lamoitier to understand the obstructive attitude (to the metric system) of certain persons in the United States, if he would think of the probable attitude of Continental Europe, supposing it had as uniform a system of weights and measures as we have here, while we were involved in the European chaos of to-day. It is not very difficult to imagine the contempt and ridicule that would be heaped upon us by the French and Germans, if, under such circumstances, we should ask them to adopt one of our systems on the sole ground that its units were divided by ten.

Next comes the remarkable statement that "there are fewer reasons than there were sixty years ago for not adopting a system that has been approved in the entire world and which is official in a number of countries" (meaning the metric system). The increase during the past sixty years of the business transacted with English weights and measures has multiplied many times the difficulties and objections to upsetting that system. M. Lamoitier assumes too much when he says the metric system has been approved in the entire world. It may have been made official in a number of countries, but the stamp of officialdom in many of these countries is practically the only backing it possesses.

The inefficacy of law in changing established usage in weights and measures is told by the following extract from the proceedings of the Paris Metric Yarn Congress (page 26):

> *M. Edward Simon.*—We have also deemed it opportune to ask for a change in accord with resolutions of preceding congresses, in the law of 1866, which made the number of silk to indicate the weight in grams of 500 meters. This legal system has remained a dead letter.

French metric legislation of the past 120 years supplies striking confirmation of John Quincy Adams' opinion expressed 80 years ago that the interference of law with weights and measures results only in filling the statute book with "the impotence of authority and the uniformity of confusion."

The worthlessness of the so-called official sanction of the metric system as an indication of its use, is well illustrated by the case of the United States in which the metric system has been made permissive by law for over thirty-six years, and is, in fact, our only system of weights and measures bearing the official stamp.

The yarn congress which M. Lamoitier asks for at St. Louis would be nothing but a farce. His idea, as shown by his concluding sentence, is to have the decision of this congress made in favor of the metric system in advance. The Exposition at St. Louis, commemorating the separation of Louisiana from France, would be a strange place for a cut-and-dried convention to fasten the French metric system on the United States.

If we are to have a yarn congress at St. Louis, let it be one representing every part of the textile world, and authorized to cast a vote in proportion to the textile machinery throughout the world. Let the delegates be pledged to vote according to the logic of the silk resolutions of the Paris Metric Yarn Congress of 1900, which were, in effect: Whereas, the people will not use the metric standards, therefore, resolved that we will adopt the standards of the people and call them metric.

That would be a congress of common sense, and its decision would be in favor of the adoption of the English yard-pound as the textile standard of the world.

DISCUSSION PRESENTED ORALLY.

Note.—The oral discussion on Mr. Halsey's paper was opened by Prof. S. W. Stratton, of the Bureau of Standards, Washington, D. C., who was present by invitation as a guest of the Society and by the Hon. J. H. Southard, Chairman of the Committee of the House of Representatives on Weights, Measures and Coinage. Professor Stratton before presenting his remarks called the attention of the meeting to the fact that it was not an infrequent custom of United States consuls to translate the units of the country in which they were at work, into the English units and that this tendency was perhaps the occasion of the confusion referred to in the paper and certain letters. It was his opinion that while it was true that the countries avowedly using the metric system have still the old units in use, the extent of such use, or rather the predominance of these units, has been over-emphasised. If it be conceded that a universal system is needed, the first question is whether the metric system is the one or our own present system the one. In his opinion the expense and inconvenience incident to introduction are of secondary importance, while the need of a universal system is a primary importance. While there may be a difference of opinion as to the best standard, there should be no difference of opinion as to the advantage of working toward the universal standard. In his opinion the proposed law had been greatly misunderstood. It proposes to make the metric system obligatory in its own work, but at first to go no further than this. Professor Stratton's paper was as follows:

Prof. S. W. Stratton.—An experience in the use of the metric system of weights and measures, covering a period of twenty years, in which it has been used side by side with the English system in scientific work, in engineering, and in the workshop, has led me to believe that it is in every way superior to that in common use. During this experience a student has not been met who did not go right to work in the metric system without scarcely giving it a thought. A mechanic has not been found who did not readily grasp the system and prefer it in a short time. When viewed from a general standpoint the advantages to be gained by a system of weights and measures, having the same base as our monetary and numerical systems, so far outweigh all of the advantages of a system capable of continuous binomial subdivision that the latter is hardly to be thought of. This is shown by the tendency in all branches of manufacturing to decimalize our own system, rather than adhere to the common fractions. Halves, quarters and even eights may be convenient to use in ordinary affairs and mental calculations, but when carried farther than this the system at once becomes unmanageable. A decimal system does not necessarily exclude halves, quarters and even eighths. In the system of length now in common use the first subdivision is 3, the next 12, then a binomial subdivision is followed as far as 64ths; this is followed by a sudden jump to thousandths. Yet we are told that this result has been reached after forty years of experience and must remain untouched. One has but to read the history of standards of length to find that they have been anything but stable. Changes have been constantly made. They have always met with resistance, and justly so, otherwise they would be premature and much needless confusion would result.

These changes have always been made with two things in view, viz.: the production of better material standards and uniformity. The history of the efforts to bring about uniformity in the standards of Germany, France, England and even the United States, when these countries had reached the state when it was no longer possible for them to maintain separate standards in the different sections of the same country, is exceedingly interesting reading. Yet these changes were made, and each of these countries may be said to enjoy a fairly uniform system at the present time. The necessity of uniformity in each case was undoubtedly brought about by better transportation and communication, and the extension of trade throughout the countries. In each of these countries instances may be found where the old units remain in use, because trade or other conditions did not demand a change. Then again, trade with other countries has sometimes introduced traces of a different system of weights and measures. However, the general condition of the weights and measures in any of the countries mentioned should not be inferred from a few isolated cases. There are still traces of the English system of money in this country, but who would use that as an illustration, that the introduction of the decimal system of currency had not been successful in this country? A personal inspection of the weights and measures of Germany and France during three visits to those countries, which involved contact with the public, manufacturing, and the Government Bureaus of weights and measures, has convinced me that the adoption of the metric system in those countries has been eminently satisfactory, notwithstanding the exceptions that have been quoted.

A few days ago a mechanic, who is perhaps 40 years of age, who learned his trade in Germany, and who has worked in some of the leading shops of that country, was asked as to the use of the "inch," either German or English, in Germany. His astonishment could not have been greater had he been asked as to the use of the "cubit" in Germany. If this country should adopt the metric system there would no doubt be found traces of the old system for fifty years, and perhaps a hundred years, to come. The countries of the world are closer commercially than were the separate parts of each, when uniformity was established in regard to their weights and measures. We must sooner or later come to a universal standard. The same forces which have brought about changes in the past will bring about changes in the future. It is simply a question of the survival of the fittest. The two systems exist side by side in all parts of the civilized world. One or the other must in time give way. It would be more difficult to-day, either in Great Britain or the United States, to suppress the use of the metric system than that in common use. Its growth and popularity can only be explained by its merits.

The scientific world long ago settled the question of a universal system of weights and measures. Scientific men may occasionally use the inch. However, it may be said in a general way, that the scientific world enjoys a universal system of weights and measures, and any one who has come in contact with this world fully appreciates what this means. The advantages which have made the metric system universal in all scientific work are equally important in commerce, in manufacturing, and in the affairs of every-day life. The application of scientific work to engineering, manufacturing, and commerce, are so frequent that it is not economical to maintain two sets of standards as exist to-day.

It is especially gratifying to note that there is a rapidly growing sentiment in favor of the adoption of the metric system on the part of manufacturers and business men of the country. The very spirit of progress which has made our manufacturers leaders of the world will not allow them to forego the advantages of an improvement, because that improvement is difficult to make.

The importance of fundamental standards in the manufacture of machinery is certainly well understood by anyone who has given the slighest attention to such matters; and while I believe that the standards of the metric system are far superior in every respect to those now in use, I repeat the statement, that any change in the standards used by manufacturers of machinery should be brought about by their own action. The history of technical standards does not indicate that they have been brought about by legislation. Why should they be in the future? This may seem "funny" to the author of the paper under discussion, but it is nevertheless a fact. The Government has never enacted laws in reference to standards, except in connection with its own work, and if the Government sees fit to use the metric system of weights and measures in some or all of the branches of its work, it has a perfect right to do so. This would involve its use only in such work as originates in the departments. If at a later date the metric system is made the sole legal standard, it can mean no more than that all business of the departments with the public must be carried on in the metric system; but who for a moment would suppose, even in this case, that if the Government should buy a machine tool the parts of that machine would necessarily have to be constructed in the metric system? If the metric system becomes the system in common use in this country it will be through laws enacted on the part of the different States, and the States have not fixed standards, except for commerce and trade. A great deal of concern has been shown as to the situation which would result in case the bill now pending before Cngress becomes a law. I cannot conceive any other condition than that stated above.

In the paper under discussion reference has been made to certain statements made before the Committee on Coinage, Weights and Measures, of the House of Representatives. The foundation for the statement that the Carnegie Company were about to issue a hand-book in the metric system was that a gentleman, in whom I have the utmost confidence, stated that he had seen such a book and was told that it was to be reissued. Upon further inquiry I find that this book was in the form of a Spanish catalogue, and that a reissue was not made on account of the plates being destroyed by fire. I have myself recently seen a copy of this catalogue, and talked with the gentleman who prepared it. Its material is taken bodily from the hand-book—dimensions and properties of materials being in the metric system. It was not intended that this statement should convey the idea that steel was being rolled to metric dimensions, but that the present forms could be used in structural work with metric dimensions. An examination of these forms will show that the dimensions are carried out to the thousandths of an inch. The same dimensions expressed in centimetres and hundredths of a centimetre would be sufficiently accurate, and would be little more difficult to handle than the dimensions now used in such material.

The origin of the statement that the National Tube Works had one of its largest mills fitted up for turning out work in the metric system was as follows:

In fitting up the machine and instrument shop of the National Bureau of Standards it was desired to use the metric system. Several letters were addressed to the manufacturers of small tools and supplies as to what small tools and supplies could be secured according to metric measurements. As a result of this investigation it was found that all of the small tools, including drills, taps, dies, reamers, arbors, etc., needed, could be secured in the metric system, and the shop has been fitted out accordingly.

From a letter received from the First Vice-President of the National Tube Works, and dated Pittsburg, March 11, 1902, I quote the following paragraph:

> One of our largest mills, that located at McKeesport, Pa., is equipped to make material for export, and for this trade we are obliged to use the metric system, so that we should probably be in a position to furnish anything in the way of tubular goods that may be required by your department made according to the metric system of weights and measures. Your impression that we manufacture other tubing than gas, steam and water pipe, is correct—we manufacture probably everything that is turned out in the way of tubular goods.

Here again the statement was made to show that material of construction could be obtained in metric dimensions—a very essential matter if the Government is to introduce the metric system. It is not unlikely that in the product of materials to metric dimensions many manufacturers measure the dimensions in thousandths of an inch, but what does this matter so long as the required dimensions are produced with a sufficient degree of accuracy?

It is not at all improbable that manufacturers will some day decide to adopt standard wire and sheet-metal gauges. When this is done it is hoped they will be in the International Metric System. No one appreciates more than I the energy, ability and progressiveness which has brought the American manufacturers to excel the world in many of our products; especially is this true in the manufacture of machinery.

Those who were fortunate to visit the exhibition of machinery at Düsseldorf this last summer must have been impressed with the fact that if we are to retain this supremacy it will be by progress, and not by saying, "Let the world come to us." Germany has been dependent upon us very largely for machinery in the past. She is endeavoring to get along without us just as soon as possible. The use of American machinery in Germany has undoubtedly brought about to a certain extent the use of our system of screw threads, but it cannot be said to be the system in common use, and its use is on the decline rather than on the increase.

The Advance Sheets on Consular Reports for November 24, is taken up entirely by a report by the Hon. Frank A. Mason, Consul-General at Berlin. He enumerates articles for which there is a demand in Germany, and in which a more or less prosperous export trade has been developed by exporters in the United States, who take the trouble to secure good connections and proceed by proper methods. In the item concerning machine tools and machinery is found the following statement:

It is well known that Germany is now passing through a period of industrial depression, and has to a great extent restricted the erection of new manufacturing establishments which, during the period from 1898 to 1900, made such large demands on the purveyors of American machinery and tools. It is also true that those imported lathes, planers, milling and other machines, have been used to reproduce themselves and to make many kinds of machinery and tools so excellent in quality and cheap in cost that Germany has become a self-supporting exporter of many such appliances which were formerly imported from the United States. But while all this is true, there is still a demand in this country for many special forms of machinery and other manufactures of iron, which is only apparent to those directly concerned in that class of trade.

Toward the end of the Report the following paragraph is found:

It need hardly be repeated that in all the foregoing, whether relating to dried fish, fire extinguishers, goose fat, or machinery, the point should always be kept in mind to make everything as plain and easy as possible for the buyer. Americans seem generally unable to realize that a nation which aspires to do a large export trade must, as a rule, deliver its goods in the country where they are to be sold and consumed. Not only this, but they must be offered in language, weights, measures, and values which the merchants and purchasing people of the country can understand. The theory that catalogues and price lists in American weights, measurements, currency and terms of payments will draw orders, provided the claim of superior quality is made strong enough, has been fatally exploded by experience.

I do not quote this as evidence that it is absolutely necessary to change the dimensions of machines shipped to Germany, but to show that there is a need for the adoption of the metric system if we are to develop commerce with foreign countries. It would naturally be supposed that a German manufacturer would give the preference to a machine built in the system of units with which he is familiar, all other things being equal.

The question is also asked: "Why should we go to France or Germany for our weights and measures?" The reply is: "Because they have something that is worth going for. We should not hesitate to accept that which the leading thinkers of the day have pronounced good, merely because it is French or German.

Reference has been made to the report of John Quincy Adams upon the metric system. Mr. Adams evidently intended to present both sides of the question—both the advantages and the disadvantages—as he saw them. In fact, in summing up the conclusions of his report we find the following statement:

> In freely avowing the hope that the exalted purpose first conceived in France may be improved, perfected, and ultimately adopted by the United States and by all other nations, equal freedom has been indulged in pointing out the errors and imperfections of that system, which have attended its origin, progress and present condition.

And the report is concluded with the following statement:

> France first surveyed the subject of weights and measures in all its extent and all its compass. France first beheld it as involving the interests, the comforts and the morals, of all nations and of all after ages. In forming her system, she acted as the representative of the whole human race, present and to come. She has established it by law within her own territories; and she has offered it as a benefaction to the acceptance of all other nations. That it is worthy of their acceptance is believed to be beyond a question.

The report of Mr. Adams, while unfavorable to the adoption of the metric system at that time, certainly cannot be classed as unfavorable to its ultimate adoption. Especially is this true since time has shown that many of his objections were without foundation. The system has stood the test of time. Its use has gradually extended throughout the world, and it is the only system which may claim any pretence whatever of being a universal system.

Reference has also been made to the report of Professor Davies in the following statement:

> The reports of John Quincy Adams and of Professor Davies represent the conclusions of the only American investigations of this subject worthy of the name which have ever been made.

It is suggested that Professor Davies' report be read in connection with President Barnard's address on the "Metric System of Weights and Measures," delivered before the convocation of the University of the State of New York, at Albany, August 1, 1871. Some of the arguments in the paper under discussion are similar to those contained in Professor Davies' report. President Barnard's address was intended as a reply to this report, and answers many of the objections raised.

Mr. F. A. Halsey.—In reply to Professor Stratton, I would like to observe, first of all the reader will be impressed by the manner in which Mr. Stratton fails to make any specific reply to my facts or deductions. He is the prime mover of the present pro-metric movement. We have a right to expect from him, of all men, a definite statement of the advantages which are to compensate for the cost of the adoption of the system; but he deals in nothing but generalities. When the leader of the metric advocates thus practically ignores my oft-repeated question, What is it all for? the unbiased reader can only conclude that he fails to accept my challenge and names the advantages because he cannot name them.

The preference of Mr. Stratton and his friends for the metric system sheds no light upon the only question at issue: Are the advantages of the system sufficient to justify a century of confusion and the sacrifice of all mechanical standards?

The favorite statement of the metric advocates, that there is nothing to prevent the dividing of metric units by successive halvings is disingenuous. The advantages claimed for the system are based on the decimal division of its units. To divide its units by successive halvings is to surrender everything characteristic of it except the interrelation of the units, which is of such slight importance in the practical affairs of life as not to be worth considering.

I do not think that the extent to which I have shown old units to be still in use in metric countries can be adequately described by Mr. Stratton's word "trace." Who except a metric advocate could compare my exhibit of facts with the "traces of the English system of money in this country?" What is the testimony of one German mechanic, of whose trade we are not told, and who, for all we know, may have been a scientific instrument maker, worth against the mass of testimony I have presented? Mr. Stratton needs heavier ammunition than this.

"The scientific world long ago settled the question"—*for itself.* The attempt of the scientific and political worlds to foist this thing upon the industrial world is one of the monumental pieces of assurance of the past century. In this connection it may be advisable to state the difference between scientific and industrial measurements. The scientific use of measurements consists of the measurement of existing things. The industrial use of measurements consists in the making of things to a required size. In the scientific use of measurements a standard size is exactly the thing we do not expect to find. In the industrial use of measurements we use standard sizes habitually, and have certain standards which we wish to preserve, but this we cannot do if we change our system of measurements. A scientific unit of measurement may hence be changed with comparative ease; an industrial unit with great difficulty. Add to this the enormously greater relative and actual use of computation in scientific as compared with industrial work, and we have a complete explanation of the different attitudes of scientific men and manufacturers on this subject.

The fact that the Government does not establish standards has no application. The point is that in this bill the Government is doing all in its power to destroy existing standards.

There is no question regarding the right of the Government to adopt the system—the question relates to the wisdom of that act. The bill would "involve its use only in such work as originates in the departments." In other words its purpose is to bring about a Government metric system and a common English system. It will further introduce an abrupt break in the equipment of the army and navy, while the product of the navy yards will be in one system and their equipment in another—and this is to be done in the name of uniformity.

So have I seen the Spanish catalogue of the Carnegie Steel Company, and there is no excuse for any one's confounding it with that company's English hand-book.

Commercial men have little knowledge of what is meant by the "adoption of the metric system." The National Tube Works receives orders expressed in metric units. These are filled as Mr. Patterson has said in paragraph 4, with goods made to the nearest equivalent English dimension. The orders are filled, and the first vice-president obviously supposes that to mean that the tubes are made to metric dimensions. Of course, the letter of Mr. Patterson, in paragraph 4, is authoritative as is this statement in a more recent letter:

"This company is not in favor of any movement looking toward a radical change in the standard of measurements."

"The use of American machinery in Germany has undoubtedly brought about to a certain extent the use of our system of screw threads, but it cannot be said to be the system in common use." Screw threads based on the inch (true or modified Whitworth standard) are in practically universal use in Germany, including the ships of the German navy. This is known to everybody who knows anything about German machine-shop practice.

I can see nothing pertinent to the discussion in Consul-General Mason's report, except that goods "must be offered in language, weights, measures and values, which the purchasers of the country can understand," which I have discussed in paragraph 80. The opening sentence of the paragraph following the extract from Consul-General Mason may be stated more briefly, thus: "it is not necessary to use the system, but we ought to adopt it"—the meaning of which is too profound for me.

"It is the only system which may claim any pretense whatever of being a universal system." The amount of manufacturing and of international commerce done in the metric system is small compared with that done in the English system.

Mr. Stratton has quoted some of the passages from John Quincy Adams, to which I refer in paragraph 7, as seemingly inconsistent with the report as a whole. These passages should be interpreted in the light of those given in paragraph 6. "As this system is yet new, imperfect and susceptible of great improvement." "It is believed that the French system has not attained that perfection." Following are additional extracts of the same import from page 215. "But that system is not yet complete. It is susceptible of many modifications and improvements;" also, "Time and experience have already dictated many improvements in its mechanism, and others may and undoubtedly will be found necessary for it hereafter."

There can be no doubt that the few general expressions of approval refer to the system as thus improved, one of the improvements which Mr. Adams expected being the relaxation of what he calls, "this decimal despotism." Note that even the quotation offered by Mr. Stratton speaks of the system as "improved" and "perfected," before its adoption by the United States. "Time has shown that many of his objections were without foundation." Why does not Mr. Stratton name them? *He cannot.* Time has only strengthened Mr. Adams' objections and added another greater than all—the anchoring of existing units in manufacturing industry.

Will the reader please recall that Mr. Stratton is the leader of the present metric movement, and will he then please read again his discussion with a view of finding a statement of the advantages which are to recompense us for the confusion and sacrifice due to the destruction of all mechanical standards; or for any proof that such standards will not be destroyed? Will he search for anything except glittering generalities and general assertions and denials that mean nothing? What is it all for?

The Chair then called upon Hon. J. H. Southard, who spoke as follows:

Hon J. H. Southard.—I came here not expecting to say a word; I came to listen and, if possible, to learn. I see that a conspiracy has been formed against me, and this is the result of it. I think, though, you will have to suffer with me. At the outset, I wish to say that I disclaim any special knowledge of this subject. I am neither a mechanic nor a mechanical engineer. I have heard a great deal of the metric system. I know a good deal of what other people say and have said about it. I have heard a good many things about it, and, so far as I have been able, with my limited knowledge of mechanics and matters in general, I have tried to find out whether these things are true or otherwise. A good many people take a very narrow view of this subject. One man said he didn't want it. I said why? He said because it is French. I have always taken the position that it doesn't make any difference whether it is French or something else, so long as it is good. It put me in mind of the story of the old lady who prayed for bread. She was a very devout woman, and her custom of daily prayer was this: she would regularly kneel by her broad fireside and pray for that which she most needed—and that was bread. One of her neighbors, knowing this, climbed to the top of the house, and during the old lady's prayer dropped a large loaf of bread down the chimney, where, to her amazement it bounded out on the hearth. Then she began very fervently to thank God for so quickly answering her prayer; and while she was doing this, the neighbor clambered down from the house-top, entered the room and said, "Don't thank God for that bread; I brought it myself." She replied, "The devil may have brought it, but God sent it just the same," and went on praying. Now, if it is good, whether it is

French, or English, or German, or Spanish, we want it. The desirable thing is a universal system of weights and measures. I have never yet found a man who has not professed to believe that if we could have a uniform system of weights and measures throughout the world it would be a consummation most devoutly to be wished. The questions are: "What should that system be? How shall we get it?" I have been a member of the Committee on Coinage, Weights and Measures, of the House of Representatives for about eight years, and during that time we have had several hearings on this question. We have invited before us from time to time men who are supposed to have had the greatest experience possible in both systems of weights and measures, men who had been abroad, men who have had not only practical experience but wide opportunity for observation. We held an investigation, what we call hearings, during the last session of Congress. I will tell you what we did. We knew that scientific men are practically a unit in favor of the metric system. We knew that men engaged in educational pursuits all over the country are for it almost to a man. We said it is of no use to call in those people; we know what their sentiments are now. We said let us direct our inquiries to the quarters from which we may expect some opposition. We determined upon that course. We knew that there was some opposition among the members of this Society. We knew that among the mechanical engineers, among the machinists, there were some who oppose the adoption of the metric system. Wherever we knew of a man whose opinion we thought would be valuable and knew that he was against the metric system, he received an invitation to appear before our Committee. In other cases we requested firms and corporations to send representative men before the Committee. Mr. Bond is here; we knew he was somewhat opposed to the adoption of the metric system, and we sent him an invitation. I think we sent one to Mr. Coleman Sellers; I know we sent him an invitation, and we knew that he was not in favor of its adoption. We sent an invitation to the Brown & Sharpe Company, and to other tool-making concerns; to the National Bridge Company; to the Baldwin Locomotive Works, and to the great iron and steel and electrical manufacturing companies of the country. We sent invitations to merchants and manufacturers, a great many of them. We thought that any existing opposition to the adoption of the metric system would develop from these sources.

Now, the result of all this is the pamphlet of testimony that I have here. This does not contain all that was said or done before the Committee. A great deal happened after this went to press, but it does contain the testimony of quite a large number of those who appeared before the Committee. The result was the same as at the previous hearings—the testimony was overwhelmingly in favor of the bill that we were considering. That does not mean the adoption of the metric system generally throughout the country. It means, if the bill passes, the adoption of the metric system; that is, the use of metric weights and measures, by the departments of our general Government. It does not mean anything in a compulsory way. There is not a word in this bill looking to compulsion. Compulsion was not thought of in connection with the matter. You know, theatrical people have a way of testing plays before they put them permanently before the public; that is, they get ready to produce a play, and then they designate some town where they will go and give the first performance of it. They call that trying it on the dog. They want to see what effect it is going to have. Well now, this is a proposition to try this matter on the dog—to try it on the Government first. If the Government cannot stand it, then we have no right to ask the people to stand it. There is nothing in the provisions of this bill which will in any way interfere with your business. I have got a copy of the bill here, and with your permission I am going to read it. It is very short. I will omit the heading and formal parts:

> That on and after the first day of January, 1904, all the Departments of the Government of the United States, in the transaction of all business requiring the use of weights and measures, excepting in completing the survey of public lands, shall employ and use only the weights and measures of the metric system; and on and after the first day of January, 1907, the weights and measures of the metric system shall be the legal weights and measures of the United States.

Now, what is there in this bill which looks towards compelling any one to do anything except in the departments of the Government? We take it for granted that if we pass a measure of this kind it will be enforced in the Departments of the general Government by executive order. This bill has been submitted to the Attorney-General of the United States, and he agrees with us in saying that there is nothing of a compulsory nature in the bill except as stated. The latter part of the bill might indeed be eliminated as surplusage, if thought wise or necessary. You might say that the German language should be the legal language after a certain date. This would not compel any one to use the German language. It would not prevent the use of the English language. You will say, then, what is the use of the bill? What is the purpose of it? I will tell you. It is to simplify and bring about uniformity in weights and measures in the departments of the general Government in this country, and their use in the departments will do much to familiarize the people with the metric measures. Some of the bureaus now use exclusively the metric system. They deal in metric units entirely. The testimony of the Surgeon-General of the United States, Surgeon-General Sternberg, is contained in this pamphlet that I have here. He issued an order that after three or six months—I have forgotten the length of time—everything in his department requiring weights and measures should be in the metric system. Now, he tells us here that he never had a particle of trouble with the system after the date first set for its use.

The argument of the gentlemen who presented the paper here to-day reminded me very forcibly of a great many of the arguments that we have heard in favor of the adoption of the system. He says that the weights and measures in use in the textile industry are in almost hopeless confusion. We have no doubt about the confusion which exists in the textile industry. Is that any reason why we should say we cannot remedy the situation? I think not. The worse the situation, the louder the call for a remedy. I had a conversation with a gentleman here to-day who said that if this bill should become a law it would cost him $100,000. I ask you why? Tell me why? Comparatively few of our manufacturers manufacture for the Government. Why should it cost anybody who does manufacture for the Government any considerable sum? Suppose a manufacturer has made a machine for the Government, and suppose the Government should leave an order with him to duplicate such machine, couldn't he duplicate it without any expense over and above that involved in the building of the first machine? Why not? And if necessary, he could furnish that machine to the Government in metric measurements. It would require a little computation. But wherein comes the expense? There is nothing about it which interferes with your business, I say, or with mine, in any degree whatever. It simply requires the Departments of the Government, in the transaction of their business, to use the weights and measures of the metric system. If it operates well there it will popularize the metric system in this country.

Now, as has been stated, we have these two great systems of weights and measures in use side by side. The metric system is only a little over 100 years old. During that time it has encircled the globe. More people use the metric system than use the English system to-day. We have two great English-speaking countries—great in a commercial and manufacturing sense, great in population—both using the English system. What is the English system? It has its bushels, its barrels, its pints, its pounds, its long tons, short tons, gross tons, its many ratios, its numerous units having the same name but differing materially in value each from the others. Is it possible that the world is coming to a system of that kind? I have never yet found a man who would say that he believed that what we call the English system of weights and measures can ever become universal. Yes, I heard one say so here to-day, but he is the only one. You will find the testimony of many people recorded in this pamphlet who have said that they believe the metric system is destined to become universal. It is said that two-thirds of the people of the world to-day use the decimal system. Only a few years ago a special committee of seventeen was appointed by the English Parliament to investigate the subject, and that committee, by a vote of sixteen to one, reported in favor of the compulsory adoption of the metric system in Great Britain. I have in my possession a letter from the Secretary of the Decimal Association of Great Britian, containing the names of nearly a majority of Parliament, all of whom have expressed in writing their willingness to vote to make the system compulsory. Last summer at a meeting of the Colonial Premiers of Great Britain a resolution was sustained unanimously advocating the compulsory adoption of the metric system. Their foreign representatives have spoken in its favor. The tendency of the world is in one direction. Nobody has ever heard of a country which has adopted the metric system, and is using it, that has ever said anything about going back to the old system. Doubtless in the textile industry in France, Germany, and elsewhere, and perhaps in other industries, weights and measures are in a state of confusion; but I am satisfied of this, that we use the metric system very much more largely than the countries mentioned use any other system than the metric system. So far as I have any knowledge the tendency is all toward the metric system. The adoption of the metric system has been recommended by the departmental officers of our Government. The last four of five secretaries of the treasury, after careful investigation, have recommended the adoption of the metric weights and measures as our standards. This legislation which is now proposed is in line with what we believe to be public opinion. We may be wrong about it. We have no feeling on this subject one way or the other. We have no reason for viewing it otherwise than calmly and patriotically.

Our proposition is to let the Government try it. We may learn then whether or not it is a good thing. If it is a good thing, we all want it. We know how close to the body politic you gentlemen are. We know how important a part you play in the commercial affairs of this country. We know how closely you are associated with industrial progress and all that. Yet we know you are not the whole thing. There are others. [Laughter and applause.] You are good people, and we like you, but we shall not get "mad" if you don't think just exactly as we do.

I believe that the metric system is coming just as surely as the tides are going to continue to rise and fall. The tendency is all in that direction. I cannot see it in any other way. Now, the question is, if we are going to have it ought we not help it along a little? If we are going to have it at all, the sooner we get it, the better. Now, why can't we try the experiment on the dog? It is not going to affect you at all; it is not going to affect your institution, Brother Christie. In my judgment, it is not going to cost you a dollar.

Mr. Christie.—I think so, too.

Mr. Southard.—And so do the majority of the people, after they study this bill and the probable effects of it. When I commenced talking, I thought about the only word I cared to say was this: don't do a rash thing. Don't jump on a thing simply because you don't like it, because some other people may like it, and it is not going to affect you. A good many people would like to see this experiment tried. A good many people—and good people, too,—believe just as I do, because they have made me believe as I believe. I am a somewhat recent convert myself. They believe that the metric system is coming; that it is here, and here to stay.

Now I am going to read you a few lines from the hearings just referred to and from the testimony of Wm. Whitman, ex-President of the National Wool Growers Association. During his remarks before the Committee he read from an address of

Benjamin Apthorp Gould, delivered before the Commercial Club, of Boston, in 1888, as follows:

"In the year 1850 was published a remarkable and useful book by Mr. John H. Alexander, of Baltimore, entitled 'A Universal Dictionary of Weights and Measures,' and giving the values of standard weights and measures reduced to those of the United States. It contains 5,227 weights and measures, with their equivalents. Leaving aside all which are professedly distinct units, I had the curiosity to count the number of different kinds of pounds, feet, inches, pints, etc. Taking, for example, the various sorts of inches, and using not only the English word "inch," but the corresponding words in other languages, *pouce*, *Zoll*, etc., I found 60. For foot, Fuss, pied, etc., there are 135. There are 53 different distances called miles, and 29 sorts of pints, while for pound, Pfund, livre, etc., there are no less than 235!

"The utter confusion created by this uncertainty need not be described. Probably most of you, gentlemen, may have had some experience of it, although the introduction of the metric system throughout the European continent has already brought relief. But, until the recent unifications of Italy, of Germany, and of the Austrian Empire, almost every petty state had its own measures, and these were changed by law from time to time. Even now, those of us who wish to know the value of various units in England find plenty of trouble. If we are told that something weighs so many stone, or measures so many quarters, it requires a considerable amount of knowledge or experience to obtain the corresponding idea.

"The weight of a human being is generally given in stones of 14 pounds each; but for glass a stone is 5 pounds, for meat it is 8 pounds. In Scotland it varies, in different places, from 17 to 22, etc. Then, as to the sort of pounds, we must ask whether they are Troy pounds, and, if so, whether Scotch or English, or tron, or the now customary avoirdupois pounds. A "quarter" may be the imperial quarter of about 8¼ bushels or the Winchester quarter of just 8 bushels; yet, when we come to bushels, there are some 40 different sorts—according as we may be measuring apples, or barley, or beans, or bran, or coal, or corn, or salt, etc."

Now, is it at all probable that the world is going to take up and make universal such a system as that? So far as I know there is scarcely anybody who entertains any such notion. We must get something a little more definite, something a little less confusing. The metre is the same the world round. So is the liter and so is the gram. That is one great advantage that the metric system has over ours. (Its decimal character throughout, and the simple relation between the units making it possible to derive all others from the unit of length, its elasticity, the ease with which it is learned and remembered are others.) It is in perfect accord with our system of notation, thus adding to the accuracy and facility with which computations may be made. That which chiefly commends it to us at this time, however, is the fact that it will become in time the universal system

I want to say to you that there is nothing in this bill to get excited about. I would like to have somebody tell me how it can affect any one of you injuriously? You could furnish the same machine to the Government that you have been furnishing, in the same way; you could express its measurements in the terms of the metric system, if the Government required it. You can do that with a resolution or without a resolution.

I think that the purport of this bill has been misapprehended entirely. I would be very glad now to answer any question that any of you gentlemen would like to ask me, if I can, but I think I have taken up more time than I should.

A Member.—I would like to ask Mr. Southard a question. Mr. Southard, you stated that this bill does not contemplate any compulsion at all. You also stated that it was contemplated, metaphorically speaking, to try this legislation upon the dog—meaning thereby the general Government—first. You have further made the statement that certain departments of this Government have already adopted the metric system. Now, sir, I would like to ask whether if certain departments of the Government have been able to make the adoption of the metric system compulsory, the proposed bill would not make it compulsory upon everybody else? Furthermore, are you not making it compulsory upon the departments of the Government who have not elected to use the metric system? Are you not practically, therefore, bringing about compulsion when you say that you want the Government to try it first, because you added, that if the Government found it a good thing, it would be a good thing for all?

Mr. Southard.—I admit that so far as the departments of the Government are concerned it will be compulsory.

A Member.—Then if those departments have elected to use the metric system, when you have passed this bill and it becomes a law, you will be making it compulsory upon *all* the departments of the Government to use it?

Mr. Southard.—Yes.

A Member.—So your argument is not in line with the real aims of the bill, because when I read this bill I find that it is compulsory. It means that we must go to the metric system throughout after a certain date. How do you explain your argument to us that this is a very innocent proposition; that there is no compulsion intended, when you make the further statement that certain departments of the Government—mentioning the Surgeon-General—have under the present law been able to make the adoption of the metric standards in their departments compulsory? Why do you ask for this legislation if you do not need it?

Mr. Southard.—We have said that the purpose of this bill is to secure uniformity in Government transactions, and for the further purpose of having, as far as possible, some kind of a trial of the merits of the metric system, without seriously involving the public at large.

A Member.—Then all those departments of the Government will have to try it?

Mr. Southard.—For one bureau to use it and another bureau not to use it, would not do. For instance, for the Internal Revenue Bureau to use it and the Customs Bureau not to use it, would result in greater confusion than we now have. A representative from the Customs Department when he appeared before the Committee the other day, said, that the use of the metric standards would involve much extra work and confusion. Now, he would not have made that statement if he had given the subject a little more reflection. He said our laws all levy customs duties upon the pound, the gallon, the yard, etc., using terms of the English system. How, therefore, are we going to determine what these customs duties are without much extra work and indefinite results if we are obliged to use metric weights and measures. Well now, Congress has already established a table of legal equivalents. Professor Stratton, Director of the Bureau of Standards, came to the rescue. He said, "in measuring your whiskey, for instance, you have two or three kinds of barrels. You take the depth and length, and you determine how much bulge there is in the barrel; you make your allowance for wantage, and you attempt to measure only to the tenth of a gallon." Now, he said, "I will make you a gauge by which you can measure the capacity of that barrel in litres, just as easily as you do now in gallons, and I will convert every table in your department in three-quarters of an hour by the watch so you can make your determinations in the event of the passage of this bill just as readily as you are now doing." Of course, I am not saying that in certain cases there would not be a little confusion at first, and inconvenience, but I say it is not impracticable in any sense. It would not be the thing to have one bureau using the metric system and another bureau using the English system. We ought to have uniformity in weights and measures in the transactions of the business of the Government, and it is to bring about such uniformity and to familiarize the people with the advantages of the system that we seek to have Congress pass this measure.

Mr. Supplee.—I should like to ask the Congressman why the work of the surveying of public lands is expressly omitted from this bill?

Mr. Southard.—Of course, I did not personally draw this bill. But I will say that the Government survey is a great work; it has extended over a period of a great many years—of more than one hundred years—and it is uniform up to date in the one system. It was thought best for that reason to complete it in that system. In fact, it is nearly completed now. If any change is to be made let it be made at the proper time afterward.

Mr. Supplee.—This bill corresponds very closely, then, to the practice in our machine shops.

Mr. Kent.—If the object of this bill is not compulsory, why have in the bill the clause that it shall be the legal standard of the United States after 1907? You will force us to use an illegal standard if you insist on the bill passing as it is.

Mr. Southard.—I have already stated that that was made a part of the bill by the person who introduced it. I don't think it adds anything to the bill. We have the opinion of Attorney-General Knox that there is nothing in this bill of a compulsory character except as to the departments of the Government.

Mr. Kent.—Then why not take that phrase out of the bill?

Mr. Southard.—It is possible that the gentleman who introduced the bill thought it might have some effect. I do not suppose there would be any real objection to eliminating those words. It certainly can have no effect so far as compelling anybody is concerned, and it is a self-evident proposition to me, that without some kind of a penalty for a violation of its provisions it could not be deemed compulsory.

Mr. Kent.—I think you will remove a great deal of the opposition that exists to this bill if you will take out that clause.

Mr. Southard.—So far as I am concerned I think it is of no importance.

Mr. Dodge.—I understand that if this bill is passed all the departments of the Government must of necessity adopt the metric system?

Mr. Southard.—Yes.

Mr. Dodge.—If the bill is not passed General Sternberg, then, could go back to the old system any time?

Mr. Southard.—He could.

Mr. Dodge.—So that that is the object of the bill—to make it compulsory?

Mr. Southard.—So far as the departments of the Government are concerned, yes.

Mr. Dodge.—It is to make it compulsory on the departments of the Government, and not leave it open for them to use either system at their discretion?

Mr. Southard.—As I said before, it will bring about uniformity in weights and measures in the departments of the Government. Of course General Sternberg could now go back to the old practice if he pleased; but this has been the practice of his department for some years; I believe ever since he became Surgeon-General.

Mr. Dodge.—The bill is very short; but the explanation of its harmlessness is longer than the bill.

Mr. Southard.—That may be.

Mr. Dodge.—And it seems to me that if there is no compulsion in the statement, "The legal standard of the United States," that words could be used in the bill to make that phrase absolutely clear without having to get an explanation or even an opinion from the Attorney-General to that effect.

Mr. Southard.—I suppose there will be nothing more generally accepted than this, that the re-enactment of a law would not affect the law. The weights and measures of the metric system are now "the legal weights and measures of the United States," in a sense. In my judgment it is harmless. The Attorney-General has decided, without any reservation whatever, that there is nothing in it of a compulsory character.

A Member.—But he is only temporary authority on that. Other Attorney-Generals may think differently.

Mr. Halsey.—You tell us, Mr. Southard, that this is intended for the regulation of the business of the departments of the Government?

Mr. Southard.—Yes.

Mr. Halsey.—Does that mean the internal business of the departments, or all transactions, including those with parties outside the Government service?

Mr. Southard.—It means that in *all* transactions of the Government requiring the use of weights and measures the metric weights and measures shall be used.

Mr. Halsey.—But there are in all transactions two parties. If the departments are required to use the metric system, how is it other than compulsory on the other party to a transaction with the Government?

Mr. Southard.—It might be, as I said at the beginning, that a department officer would present his specifications for a machine, for instance, in metric terms so far as weights and measures are concerned, and the builder of the machine would be required to accept them and work to them.

Mr. Supplee.—Is he not required to do so by the terms of this very bill?

Mr. Southard.—Yes, but supposing you have made a machine for the Government, and the Government wants another machine like it, are you going to refuse to build that machine because its dimensions are stated in metric units. Would you refuse to build *any* machine because its dimensions were so stated.

Mr. Halsey.—Why, sir, do you call *that* the adoption of the metric system?

Mr. Southard.—So far as this bill is concerned, yes.
the dimensions of which are expressed in metric units, it does not seem to me that it would be a very difficult thing to get it made. The impression seems to have gained ground that the moment the Government shall require a machine, or any other product, to be built in metric measurements, you will be obliged to change your standards all through your shop. Nothing of that kind is further from the fact, and most of you who have been before the committee have come to that conclusion. There is nothing in the bill that will require anything of that kind. If the Government asks for a different machine from that which you have been making, you will make it, and it will not make any difference to the Government, and not much to you, whether you measure it by a metric rule or not.

A Member.—What, then, is the object of this bill?

Mr. Southard.—The object of the bill, as I have already said several times, is to bring about uniformity in weights and measures in the transaction of the business of the Government, and to give, so far as possible, without interfering with the business of the general public, the metric system a trial.

Mr. Warren.—If this is all so plain, why wouldn't it make it much more plain to eliminate the last clause of the bill?

Mr. Southard.—So far a I am personally concerned, I have no objection to doing that; but the bill has been reported in the form in which it now is, and it was not thought at that time that this clause would be an objectionable feature at all. That feature of the bill was not dwelt upon. The point that I have just stated seemed to be the great objection to the bill—that the adoption of the metric system by the departments of the Government, as provided in this bill, would require shops to change all, or many of their standards.

Mr. Halsey.—You tell us, Mr. Southard, that this thing does not involve the changing of the sizes of our machines. Then why all this talk about the cost of new tools, etc.?

Mr. Southard.—There is no necessity for that.

Mr. Halsey.—Mr. Stratton says it would cause changes.

Mr. Southard.—That contemplates a step beyond.

Mr. Halsey.—I should say so.

Mr. Southard.—If we are going to adopt this system, we would like to be certain we are right about it. If it is a good thing for the Government it is a good thing for everybody. We believe the saving of cost in the education of our children year after year would be more than the whole cost to all of the manufacturers of the United States incident to the introduction of the metric system.

A Member.—I would like to ask whether in the case of selling machinery or any product to the Government they would accept the nearest equivalent to the metric measurements? If you were buying 60-inch lathes, for instance, would you accept the nearest equivalent to the metric measurement?

Mr. Southard.—Every measurement is really approximate, and I presume there would be no doubt about that. Of course I do not know what the Government officers would do in such a case. I think the officers of the Government are inclined to be reasonably accommodating. For instance, if you are selling a pump to the Government, a pump furnishing so many gallons per minute, you would take the equivalent in litres. If that amount of latitude were allowed, I should think a great many of the objections that many of you gentlemen make would disappear.

Mr. Miller.—I would like to ask one question of the congressman. Admiral Melville is the chief of the Bureau of Steam Engineering. Has he been registered in favor of the metric system?

Mr. Southard.—I do not want to say that Admiral Melville's testimony is entirely in favor of the metric system. He has said this, however, that he believes the adoption of the metric system is eventually inevitable; that he thinks it is entirely practicable; and that he believes that his department could very well use the system. He says he thinks that it would cause some extra expense to the Government; that the matter of the expense in running his department would be the great objection, if any, but if the Government will only give him the money he can use it.

Mr. Miller.—And Admiral Bowles is the head of the Bureau of Construction in the Navy. What does he say about it?

Mr. Southard.—He was invited to appear before the committee, but he did not respond. The representative from his bureau, however, opposed the proposed legislation.

Mr. F. A. Geier.—I would like to ask Mr. Southard a question. Mr. Southard, you stated that this bill does not contemplate any compulsion at all. You also stated that it was contemplated to try this legislation first upon the dog—meaning thereby the Government. You have further made the statement that certain departments of this Government have already voluntarily adopted the metric system. Now, sir, I would like to ask whether if certain departments of the Government have been able to make the adoption of the metric system compulsory, would not the proposed bill make it compulsory upon everybody else? Furthermore, are you not making it compulsory upon the departments of the Government who have elected to use the metric system? Are you not practically, therefore, bringing about compulsion when you say that you want the Government to try it first? Because you added that if the Government found it a good thing, it would be a good thing for all.

Mr. Southard.—I admit that so far as the Government departments are concerned it will be compulsory.

Mr. Geier.—Then those departments, not having elected to use the metric system, when you have passed this bill and it becomes a law, you will be making it compulsory upon all the departments of the Government to use it?

Mr. Southard.—Yes.

A Member.—So your argument is not in line with the real aims of the bill, because when I read this bill I find that it is compulsory. It means that we must go on the metric system throughout after a certain date. How do you explain your argument to us that this is a very innocent proposition, that there is no compulsion intended? You make the further statement that certain departments of the Government—mentioning the Surgeon-General—have under the present law been able to make the adoption of the metric standard in their departments compulsory. Why do you ask us to let this bill go through Congress if you do not need it?

Mr. Southard.—We have not asked you to let it go through. What we have asked you is this. We have said that the purpose of this bill is to secure uniformity in Government transactions, for the purpose of having, as far as possible, some kind of a trial of the merits of the metric system, without seriously involving the public at large.

A Member.—Then all those departments of the Government will have to try it?

Mr. H. R. Towne.—I think one reason why the bill presents objectionable features to the interests represented here, is that many of the manufacturers here present, and still more to those who are affiliated with this society and what it stands for, are producers of material of which the Government is a consumer. Now, if the Government is going to demand that material in different dimensions from those that are standard, either a manufacturer must decline to deal with the Government or must incur great additional expense in providing special tools for the making of that material; and I believe that a great part of this opposition would be removed if the bill included a proviso that any of the departments of the Government, in the purchase of standard material, while perhaps requiring to have the dimensions stated in metric units, could adopt existing standard dimensions.

Mr. Southard.—Is there anything in the bill which would prevent any departmental officer from doing that?

Mr. Towne.—That is what we are afraid of. We are afraid that under the provisions of the bill the officials of the Government will so determine, and will say to us that if we want to furnish such and such material to the Government we must comply with the letter of that bill in every particular. Now, if you make it permissive, not compulsory, that they may use existing dimensions, I think it will remove much of the objection to the bill in its present form.

Mr. Spencer Miller.—For example, I represent a manufacturer of ships' winches. A standard winch is catalogued in the English system. In case this bill becomes a law the Navy Department would have to send the order for that winch in the metric system. We will say that it has 7″ × 10″ cylinders. Now, they must reduce those dimensions to the metric system.

Mr. Southard.—You have numbers, have you not, for these different winches?

Mr. Miller.—No; not necessarily.

Mr. Southard.—If they were numbered, why, the Government might order them by the number.

Mr. Miller.—In the case of a special winch, desired by the Government, they would be obliged to specify it in the metric system. Now, how are they going to use the metric system that agrees with a 7″ × 10″ cylinder? Is the department going to produce working drawings for a winch specially contrived for them that is going to have the metric equivalent of a 7-inch bore?

Mr. Southard.—I would see no necessity for it.

Mr. Miller.—Then the two things go on board the ship, and the parts are absolutely non-interchangeable.

Mr. Southard.—You would not stamp your dimensions on your winch. So I do not see how it is at all material.

Mr. Miller.—If you had ever worked in a machine-shop you would see.

Mr. C. R. Gabriel.—I would like to ask, along the line of thought of the last speaker, this question. The congressman says the Government will require the dimensions of a machine to be expressed in metric units, but the builder can make the machine just the same as before. Now, for illustration, suppose the machine has a shaft 2 inches in diameter, the nearest metric equivalent would be 50 millimeters, or 1.970 inches. The builder would have to make special tools, or the Government would have to accept the shaft 2 inches, expressed as 50 millimeters and a fraction, which is a very undesirable thing, as all builders of machinery know, the effort being to cut out all fractional dimensions where possible.

Mr. Southard.—I do not want to be misunderstood here. I do not mean that the tendency would not be eventually to make these exact sizes. That would be so, but the process would, perhaps, be rather slow. You work with vulgar fractions, and very inconvenient fractions, as I know, many times, and whether decimal or other does not make so much difference.

Mr. F. A. Halsey.—Mr. Southard tells us the desirable thing is a universal system of weights and measures. The question at issue is not is this thing desirable, but is it practicable? And a century of experience with the metric system has shown that it is not.

Mr. Southard says that an invitation to appear before the House Committee was sent to Mr. Coleman Sellers. The following letter from Mr. Sellers says differently:

"In reply to your favor of the 29th instant, have to say that I received no invitation to appear before the House Committee on Coinage, Weights and Measures."

The following from William Sellers & Company also explains itself:

"This company received no invitation to appear before the House Committee on the metric system, nor did any member of our staff receive such an invitation."

Mr. Southard tells us that Admiral Bowles was invited to appear before the committee, but the following extract from a letter from Admiral Bowles to the Secretary of the Navy does not agree with his statement:

"The Chief of the Bureau of Standards, of the Treasury Department, called at this bureau some time since, to obtain its views upon the subject, and was informed that they were adverse to the measure in question. He stated that the chief constructor would be given an opportunity to express his views before the proper committee of the House, but this has not occurred, and therefore the bureau considers it desirable to lay before you a brief statement of the serious disadvantages that would be incurred by the enforcement of the proposed measure in the Navy Department, and particularly in this bureau."

"Wherever we knew of a man whose opinion we thought would be valuable, and knew that he was against the metric system, he received an invitation to appear before our committee," but the most distinguished American opponent of the system, the house, which for thirty years has been the centre of opposition to it, and the chief constructor of the navy, whose views were first ascertained, were overlooked!

The critical analysis of the disadvantages of the proposed change given by Admiral Bowles is too long for insertion at this stage of the argument, but it is summarized in the last paragraph, which reads:

I am unable to see the ultimate advantage claimed for the metric system. The enormous difficulty of the entire loss of present standards is entirely lost sight of in the mere slight convenience in conversion from one system of measures to another.

Mr. Southard considers that Admiral Melville believes the adoption of the system to be inevitable and entirely practicable. The following from Admiral Melville does not agree with this opinion:

The metric system is entirely academic. It is a perfect system for the laboratory but would ruin the business of Great Britain and America. We had better attempt to teach the world a universal language.

"The testimony was overwhelmingly in favor of the bill." Two representatives of the textile industry appeared to favor the bill, but the vote taken by the *Textile World* was substantially two to one against it, and of 1,200 textile mills and textile men who were asked to vote, just 54 cared enough about the matter to reply. Mr. Southard should read the list of manufacturers which heads this discussion, all of whom but two vote against the system.

I do not believe that the American people are prepared to admit that the forcing of this thing upon the American Navy in opposition to the judgment of its chief constructor and its chief engineer can be properly described by the words "trying it on a dog."

Mr. Southard tells us "there is not a word in this bill looking to compulsion," but in his cross-examination he admits that in all transactions of the Government, *including those with parties outside the Government service*, it requires that the metric system shall be used, and by reference to the bill, paragraph 82, it will be seen that in Government business *only* the weights and measures of the metric system shall be used. The opinion of the Attorney-General that the bill does not involve compulsion relates to the interpretation of the words legal standard, and the metric advocates endeavor to so stretch his language as to make it appear that the bill has no compulsory features. How can the system be obligatory, as Mr. Southard admits it is, upon the departments in their dealings with outside parties, and not be obligatory on those parties?

The case is parallel with that of the Eight-Hour Bill. That bill is intended to compel all manufacturers who supply the Government with goods to employ their workmen eight hours only, and the Metric System Bill is likewise intended to compel those same manufacturers to use the metric system. No one will pretend that the Eight-Hour Bill is not compulsory, and no one can rightly claim that the Metric System Bill is not, in the same way and to the same degree, compulsory. To claim that it is not thus compulsory is more than untrue; it is ridiculous.

The purpose of the bill "is to simplify and bring about uniformity in the Departments of the General Government." Which is the more important, uniformity between the Navy Department and the Medical Bureau of the War Department or uniformity between existing and future ships of the navy? The Anglo-Saxon nations have substantial uniformity to-day, which no metric country has or ever has had. In no country of the world has the metric system secured uniformity; but, ignoring the experience of the world, Mr. Southard proposes to abandon the uniformity which we have, in order that after a transition period of confusion and indefinite length we may again reach uniformity Mr. Southard should heed the words of John Quincy Adams:

> Is your object uniformity? Then before you change any part of your system, such as it is, compare the uniformity that you must lose with the uniformity that you may gain.

Nowhere in the pamphlet of testimony before the House Committee does the idea appear that the adoption of the system is to be confined to the Government, nor that the purpose of the measure is to bring about uniformity in the departments. The whole discussion relates to the adoption of the system by the business and manufacturing interests of the country, the Government merely taking the lead. That Congressman Shaffroth, who introduced the bill, did not share Mr. Southard's present idea of its scope is manifest from his words, given on page 30 of the pamphlet containing the testimony:

> "The bill which I introduced names the first day of January, 1903, for the Government to adopt it, and the 1st of January, 1904,* *when the people would have to adopt it.*"

"We have no doubt about the confusion in the textile industry. . . . The worse the situation the louder the call for a remedy." *This confusion exists in metric countries alone.*

* These dates were changed by the committee to January 1, 1904, and January 1, 1907, respectively.

"More people use the metric system than use the English system to-day. *More measuring is done in the city of Philadelphia than in all of Spanish America.* Before enumerating our bushels, barrels, pints, pounds, etc., Mr. Southard should have read my table of non-metric units used in metric countries. If the investigations of the committee of the British Parliament were comparable with those of Mr. Southard's committee, their conclusions are entitled to no respect whatever. What do the colonial premiers know of the technicalities of weights and measures? This is a factory, not a political question. "I am satisfied that we use the metric system very much more largely than the countries mentioned use any other than the metric system." Rubbish! Mr. Whitman's list of 60 inches, 53 miles, 29 pints, 235 pounds, etc., has no application. These numerous units are largely from *metric* countries. No such confusion exists in the United States, nor has it ever existed. This saddling of the confusion in metric upon non-metric countries can scarcely be characterized in temperate language. Our three pounds produce no confusion, because they are used for different and perfectly understood purposes.* They have the same value throughout the English-speaking world. The confusion described by Mr. Southard, and which he attempts to saddle upon us, is the confusion due to different values of the same unit in different districts, and even towns. With the single exception of our two tons † there is not, and never has been, any confusion of this kind in the United States. These numerous units represent the confusion into which all countries except the Anglo-Saxon had allowed weights and measures to drift before turning in despair to the metric system.

So far as any meaning can be extracted from Mr. Southard's cross-examination regarding the meaning of the adoption of the metric system in the departments of the Government, it appears that he believes the departments will require from outside parties nothing more than the naming of leading or over all dimensions, giving capacities, etc., in metric equivalents. I have already

---

* Few people have ever seen a Troy or apothecaries'-pound weight. *I never saw either* and much of my early life was passed in a drug-store. The confusion of which we hear in Anglo-Saxon countries is a figment of the imagination.

† I suppose the metric advocates will cite also the Imperial and the American gallons, but of those who read this, how many have ever experienced any confusion due to these two gallons?

characterized this interpretation in anticipation as "the greatest farce-comedy of recent years" (paragraph 85), but I did not expect it would be given so soon. Is it for this petty outcome that the House Committee is holding hearings and technical societies are having discussions and taking votes? What will be the gain from such a course? Where will there be any saving of time in calculations? With such commercial measurements in the metric system, and constructive measurements in the English system, where does the uniformity come in? More to the point, however, it must be remembered that Mr. Southard is not charged with making Government purchases, nor with the interpretation of the law for the Government departments. When this law, reading "all the departments . . . in the transaction of all business . . . shall employ and use *only* the weights and measures of the metric system," reaches the Navy Department through an executive order, what right will Admirals Bowles and Melville have to interpret the word only in Mr. Southard's easygoing way. Mr. Southard thinks "the officers of the Government are inclined to be reasonably accommodating." It will not be a matter of inclination, but of obeying the law.

Finally, I would like Mr. Southard to explain how he reconciles his easygoing interpretation with the italicised words of the following extract from the opinion of the Attorney-General: *

"Indeed, as each bill † *prohibits to the departments the use of any other system*, by a familiar rule of construction, this will be taken as the only prohibition intended, and it will end there."

Mr. Southard's repeated expression of his faith that the system is bound to become universal shows that he, like most of the metric advocates, believes that if he will only repeat the statement often enough, that alone will induce others to believe it, like himself.

Mr. Southard thinks that "the purport of this bill has been misapprehended entirely." It is, I think, clear that no one understands its meaning less than he.

Mr. George S. Morison.—I have only a few words to say. It seems to me the first thing to do is to strip this whole subject of all extraneous matter, and consider simply what it is. The

* This opinion may be found in full in the "American Machinist" for March 20, 1902.

† Two bills appear to have been submitted to the attorney-general.

question is not of changes of sizes or standards, but it is a question of adopting another method of measuring existing standards. I am perfectly willing to admit that the decimal system is not the best. I myself would prefer the octal system. Some other man would prefer the duodecimal system. But if we go back to the creation and the Creator, there is nothing more true than that the Creator has made mankind with five fingers, and that fact is the basis of our decimal system. It may be that on the planet of Mars they are far ahead of us, because by having six fingers they have the duodecimal system. But if there is any one thing which has the seal of the Creator on it, it is the decimal system, based on five fingers. Then again, it is perfectly true that the metre is not what it was intended to be, and it was not a rational unit anyway. There never has been, so far as I can make out, but one rational unit, and that is the nautical mile, which is a minute of arc. But the fact remains that, rational or irrational, the metre is the only standard now of international use; and, as I understand, the only standard of any kind which is referred to as the basis of scientific accuracy is the metre preserved in Paris and the replicas which have been sent to other parts of the world. It bears no practical relation to any arc of the earth, or the meridian of Paris, or any other meridian, or of any parallel of latitude, but it is a unit which is in use. We are not called to consider what things are divine. We simply want to consider whether there will be an advantage or a disadvantage in the use of the decimal system, and if there will be an advantage in its use, whether we had not better adopt the decimal system, which is the most generally adopted. It is certainly easier to multiply 2 inches by 3 inches than to multiply the equivalent in metres, but it is not easier to multiply 1 foot $2\frac{3}{8}$ inches by $5\frac{11}{16}$ inches than it is to multiply the decimal 0.3651 metres by the decimal 0.1444. We use the decimal system in all our calculations, and the decimal system is the basis of the metrical system. In spite of the sacredness of the inch, the civil engineer has abolished it. The railroad engineer in his field work takes the tenth of a foot and throws the inch entirely away, in spite of its sacred meaning.

Let us imagine a table of logarithms in vulgar fractions, halves, quarters, etc. It would be as unreasonable a thing as the Chinese counting-board, which they use simply because they have no convenient decimal notation, although they have a decimal basis.

It seems to me this is the whole question. There is no occasion for making any change of standards. Decimals can always be used for everything within a margin of error much less than anybody can work to. You have simply to put on one more figure, and instead of an error of a ten-thousandth of a metre you have an error of a one hundred thousandth of a metre. I think that is the only question. Are we prepared to do this, or are we going to stick by our old cumbersome methods? We cannot measure everything in even metres. We must avail ourselves of the decimal sub-divisions. The matters which would be affected most are our areas of land and our land surveys, and these latter are so inaccurate that there would be some advantage in getting rid of the even numbers, which now imply an accuracy which does not exist.

Mr. F. A. Halsey.—"The question is not a change of sizes or standards, but it is a question of adopting another method of measuring existing standards." Mr. Morison is mistaken. The basic feature of the use of any system of measurements is the use in construction of such sizes as are represented by the lines on scales graduated in the system used. The use of refined methods of measurement in construction is chiefly to determine these sizes with greater accuracy. English sizes are not and cannot be thus represented by the lines on metric scales.

A change which changes nothing can accomplish nothing. The use of metric equivalents for English sizes would make no change in any manufactured product and would not increase its fitness for any purpose nor its acceptability to any customer. The only changes introduced would be in drawing office and shop measurements, and such changes would be distinctly for the worse, as they would wipe out all dimensions represented by lines upon scales.

Imagine any piece of work whatever—a drawing, a jig, a piece of framework, or a heavy casting or forging—in process of laying out. The scales used are metric, but the sizes are those marked upon English scales; that is, we imagine English sizes to be laid out by means of their metric equivalents. *In a day's work not a single size wanted would be found marked upon the scale. Every one of them must be estimated.* The question is not the measuring of existing sizes in another set of units, but the retirement of existing sizes and the substitution therefor of new ones. I have gone into this specious evasion—not solution—of the question in paragraph 53; but granting it to be feasible—which it is not—no one has ever shown how it is to secure any advantage whatever.

This matter need not, however, be left to deduction. We have the experience of the machine tool builders in changing adjusting and measuring screws, and the experience of the Brown & Sharpe Manufacturing Company in connection with small tools, which is given elsewhere in this discussion by Mr. Sharpe. The fact which stands out above all others is that to the extent which these manufacturers have used the metric system, *to the same extent have they abandoned their English standards.*

The feasibility or the reverse of this use of metric equivalents for English dimensions represents the dividing line of intelligent opinion upon this subject. That it is not feasible is as clear to me as is the truth of the multiplication table. Read the footnote to paragraph 53 and the latter half of paragraph 55.

Mr. Suplee.—I have no arguments to present, with one exception. I think it will be found that any nation which predominates in any particular branch of commerce or manufacture will carry its standards with it. That is clearly shown, I think, in the way certain British standards have preponderated in Germany and in the Spanish-American countries, to which Mr. Henning has referred. England is a great ship-building country, and the result is that vessels all over the world are measured in the British tonnage system. The nautical mile prevails everywhere. Nowhere are sea distances measured in kilometres. On the bow of every German ship in this port you will find the draught of the ship marked off in British feet. In other words, it is the commercial or manufacturing importance of the nation which carries the system with it, and not any paritcular inherent merit in the system. Whatever system the United States chooses to adopt will go wherever American manufactures go. Whatever system England adopts will go where English manufactures go. The system is secondary to the machinery back of it, and to the nation back of it. And so long as you adopt a consistent system and adhere to it, it simply depends on what you do with it and not what it is.

Mr. C. V. Kerr.—It has just been whispered to me by a gentleman whose spokesman I will be for a moment that the shape of the earth is changing, and consequently the axis of the earth would not be a fit source for a unit of measurement. I can remember for myself, it was stated in my old geography that Coney Island was gradually sinking—whether physically or morally was not stated. I have been afraid to go there since. I think the keynote of the whole question has been struck by one or two of the speakers. Mr. Morison, for instance, states that civil engineers have long ago discarded the inch and substituted the tenth of a foot, and that is right. Have not machinists done the corresponding thing? In using micrometre calipers we measure to a thousandth of an inch. Have not the old cumbersome wire gauges been largely replaced by more convenient ones? Is not that the trend of evolution, to discard those old-fashioned things that have been found useless, and won't that process go on? So far as standards of measurement are concerned, the metre and the yard, are not they both reduced to two bars of metal that are carefully preserved? Therefore, isn't one as good as the other in itself? If the shipbuilding prestige and the importance of England can establish the tonnage rating unit of the world, why cannot America ultimately, from its manufacturing supremacy, carry its own unit of measure through all the world? If we keep on the line of progress that we have been following, will it not be possible for us to force upon the rest of the world our own unit, instead of going to France for a unit which they have been trying to adopt for a century? It seems to me that the whole question comes down to the phenomenon which we sometimes see of the tail wagging the dog. The French system is destined not to be used, in my opinion, by the great mercantile and manufacturing nations of the earth. They will be the English-speaking people, and why should not the English-speaking people force their units as they force their manufactures on the rest of the world?

Mr. H. D. Sharpe.—I should like to allude to one feature of Mr. Halsey's paper and to contribute what little I know of my own knowledge.

I think one of the most common advantages which it is assumed would come to us manufacturers by adopting the metric system is that regarding the keeping, or increase, of our foreign trade; indeed, that we will have to adopt it if we wish to make further progress. Some people question whether American trade is going to increase any more at all, thinking that perhaps we have reached the summit and have got all that we can by using the English system as we have. Mr. Halsey has shown by several examples that the American tool builder has succeeded pretty well without the use of the metric system. There is a burden, it would seem to me, placed upon the advocates of the new system of really showing *how* our foreign trade could be much increased before it shall be finally adopted and used in this coun. try.

From my own experience and my own knowledge I can say that the adoption of the metric system would not increase the foreign trade by one iota—the foreign trade in which I am interested. We have sold machines for years in foreign countries made on the English system, and are finally willing to furnish screws, or their equivalents, by the substitution of dials on the adjusting screws, just as the foreign demand needs it. The question with us has simply been *does it pay?* Furthermore, we have furnished cutters, *metric cutters*, with *metric holes because it pays.* We have made metric measuring instruments *because it pays.* Another thing to which I would like to call the attention of those who think we must have the metric system in order to increase foreign trade is the fact that American tools, which are principally sold through foreign agents on the ground, are generally listed in their catalogues with metric equivalents, and not with the English expressions. For instance, a milling machine will be shown by number, and underneath it will be placed its capacity in millimetres. Turning to the metric system, then, would not alter the conditions of selling American machines in foreign countries so far as I can see.

In order to confirm my own impressions I corresponded with several tool builders and makers of some supplies, such as taps and dies, in the vicinity of our own city, and I find that their experience substantially agrees with ours. They furnish machines with metric screws and taps and dies in the metric system, or the Whitworth or the French standard system, when demanded and when *it pays*, all at practically the same prices that other goods are sold in the English system for American or English consumption.

Mr. P. A. Sanguinetti.—I would like to say to the members that some thought is being given to this subject in England. About a month ago I received a drawing from London in which the measurements were given in millimetres, and my correspondent wrote calling my attention to it, saying that they were preferred to "the barbaric feet and inches."

*Mr. F. A. Halsey.**—This paper and discussion are an effort to establish four leading propositions :

1. As shown by the experience of other countries, the changing of a people's system of weights and measures is a task of enormous difficulty, and is attended with wide-spread confusion. A few general denials of the facts regarding the persistence of old units in metric countries have been made; but the facts are overwhelming, and are of such a nature that they scarcely admit of being answered. It may, then, be considered as proven that with us, and especially without general compulsory laws, which the metric advocates disclaim, the transition period will last for a century.

2. The adoption of the metric system, meaning by that term the retirement of the inch and the substitution therefor of the millimetre, involves the destruction of all mechanical standards. Mr. Miller has said that he does not believe this, and, no doubt, Mr. Henning considers his table of approximate equivalents to apply here; but there has been no effective rebuttal of the position taken in the paper, which, therefore, I regard as established.

3. The prosperity of foreign trade in nowise requires the adoption of the system as a basis of manufacture.† With the exception of a single re-echo of the old assertions to the contrary by one of Mr. Miller's correspondents, there is not in this whole discussion a syllable of disproof of this contention, while the confirmation of it by the experience of machinery manufacturers is overwhelming. This proposition may, therefore, be regarded as not only proven, but as accepted by the metric advocates.

4. The bill now before Congress is a compulsory measure, so far as it relates to those who do business with any of the departments of the government. No reply has been made to this, and, indeed, its truth is virtually admitted by Mr. Southard. It therefore may be regarded as established.

How much remains of the metric case?

---

* Author's final closure, under the Rules.

† This is not to be understood as referring to its use in commercial literature and correspondence. It is the commonest of common sense to say that commercial information for metric countries should be given in metric units.

No. 972.

REPORT OF COMMITTEE APPOINTED TO DISCUSS THE ARGUMENTS IN FAVOR OF AND AGAINST THE METRIC SYSTEM.

To the Members of the American Society of Mechanical Engineers.

Sirs.—As a result of the discussion of the relative merits of the English and of the metric systems of weights and measures, which took place at the Autumn (1902) meeting of the Society, the Council appointed Messrs. Geo. M. Bond, James Christie, Wm. Kent and Fred J. Miller, as a committee to prepare and present a report to accompany the paper of F. A. Halsey and the discussion upon it, and to be sent to the members with the request that they vote upon certain questions pertaining to the discussion.

Upon conferring together, it was found that all the members of the committee were agreed upon the following points:

1. Legislation designed to compel the exclusive use of the metric system is not desirable.

2. We believe that such legislation could not be enforced in any event so far as transactions between private individuals are concerned.

3. The general government has the power to specify the system to be used in its own work and business, and can require that work done for it by contractors shall conform to any specified measurements or weights.

4. The government cannot compel anyone to bid upon its specifications.

5. Recognizing the well settled fact that the consumer does and must pay all necessary costs of production, we believe that if the government specifies such dimensions as will materially increase costs of production, the government and not the bidder will have to pay such increased costs, it being self-evident that a bidder, not compelled to bid, will not bid except at a price which will afford him a profit.

6. The bill now before Congress is intended to make the use of the metric system compulsory in the several departments of the government, but it cannot make it compulsory in private transactions.

7. We believe there is no force in that class of arguments which consists in taking integral dimensions in one system, translating them into equivalent and therefore fractional dimensions in the other system and then making comparisons. Such arguments can be made as strong for the one system as for the other.

JAMES CHRISTIE,
FRED J. MILLER,
GEORGE M. BOND,
WILLIAM KENT.

Having agreed upon the above points, those members of the committee who compose what may be called its pro-metric side have prepared the following statement in favor of the metric system, which will be found upon the left-hand pages following; the answering argument being upon the right-hand pages; corresponding numbers being used throughout for convenience of the reader.

Arguments in Favor of Metric System.

1. It is a rational system that harmonizes with the world's arithmetical notation, and is the only method so far proposed that bears any promise of becoming universally international, thus facilitating commercial exchanges and encouraging international trade.

2. The correlations established between measures of length, weight and volume, together with the uniform decimal enumeration, tend to facilitate and simplify computation and reduce the necessity of memorizing tables of weights and measures, thus saving time in the school, the office and the workshop, and simplifying work for all.

3. We now use a mixed system of decimal and binary fractions, and the common practice of changing binary to decimal fractions in computations and then changing back again for the result would be abandoned, together with all the sources of error to which those processes are liable.

4. The metric system, being decimal, is well adapted for slide-rule computations, consequently it is asserted that the slide-rule

Replies to Arguments in Favor of the Metric System.

1. The metric system harmonizes with the world's notation, in so far as that notation for computing is a decimal one. But it does not harmonize with the universal system of binary subdivision of measures of length. The names also of the several units do not harmonize with the Anglo-Saxon terms so largely used.

The metric system bears no promise of becoming universally international, unless the English and the United States governments should restrict the liberties of the people by compulsory legislation in favor of this system. The use of the English system in manufacturing is not an obstruction to international trade, because anyone engaged in international trade is at perfect liberty to use the metric measures in his catalogues and correspondence.

2. The alleged "correlation between measures of length, weight and volume" of the metric system, applies only to the relation between the measures of length and the weight of distilled water at a certain temperature; for any other material whatever, recourse must be had to tables of specific gravity, while in the English system reference is made directly to tables of weight per cubic foot, which are certainly just as simple and easily memorized as specific gravities. The facilitating and simplifying of computation by the metric system is true only in certain selected cases. In other cases the English system is just as simple, or simpler. As to the necessity of memorized tables of weights and measures, the tables of English weights and measures in customary use by everybody are simpler, have fewer names, and require less time in school than the metric measures. This will be shown later on page 658.

3. "We now use a mixed system of decimal and binary fractions." This is entirely a matter of choice and convenience, and anyone can use either system he pleases. The trouble of computing and changing back from one system of fractions to the other is a trouble that is experienced only by a very small fraction of the population, and those who have much computing to do facilitate their work by the use of tables of corresponding decimals and binary fractions.

4. The decimal system in itself is not the metric system, because the English system may be used decimally just the same

is more frequently used in Germany than in England, where the device originated. It is also better adapted to all mechanical computing devices and to logarithms which are not applicable to common fractions.

5. Values expressed in any one of the different metric units are translated into values expressed in any other unit with great facility and usually by simple inspection; *i. e.*, without calculation. For instance, 4 centimetres equal 40 millimetres, or .4 decimetres, or .04 metre, or .004 decametre, or .0004 hectometre, or .00004 kilometre; and all these relations after a very little familarity with the system are instantly known, almost without mental effort, though in practice the millimetre, centimetre, metre and kilometre only, are generally used.

Compare the above with the work required to determine the value of $\frac{17}{32}$ in. in fractions of a foot, yard, rod or mile.

6. The system provides units of length and of weight adapted to any and every purpose; the millimetre for ordinary machine construction, the centimetre and metre for building construction, etc., and the kilometre for all other distances which we now usually express in rods or miles.

as the metric system; in fact, surveyors use the foot and its decimal sub-division of .001 of a foot regularly in their computations, and the draftsman and machinist is at perfect liberty to use .01 and .001 of an inch instead of the binary sub-division, whenever it will facilitate his work. The fact that the binary system is commonly used in preference to the decimal system is evidence that it has some advantages.

As for slide-rule and logarithmic computations, a short table of decimal equivalents of binary fractions may be printed on the back of the slide-rule, eliminating the chances of error in computing these equivalents.

5. The measures of length mentioned here are millimetres, centimetres, decimetres, metres, decametre, hectometre and kilometre. The great facility of changing from one of these to the other is not to be compared with the much greater convenience of using fewer units—viz., the inch, foot and mile, the only three important units universally used in the English system, and the avoidance of errors due to the misplacement of the decimal points.

The particular example given, to express $\frac{17}{32}$ in. in fractions of a foot, rod or mile, is one which might be given to a child as an exercise in arithmetical computation, but it is one which is practically never to be met with in a lifetime of experience by a mechanic, machine designer or engineer. A machinist could easily measure 1 ft. $0\frac{17}{32}$ in., but what probability is there that he would ever have to record the dimension as $1\frac{17}{384}$ ft. or 1.04427 ft.? For comparison let us give a practical example in the metric system. What is the side of a square whose area is 10 hectares. Answer, 316.628 metres.

6. The English system provides units of length and weight admirably adapted to every and any purpose in measuring: the inch, with its binary or decimal sub-division as may be preferred, for machine construction; the foot, for all dimensions in building construction, up to any number of thousand feet (this foot takes the place of the usual French measures mentioned, the metre, the centimetre and decimetre), and the mile for all great distances. For measures of length, therefore, the three units, inch, foot, and mile, cover all requirements better than the five units, millimetre, centimetre, decimetre, metre and kilometre. The yard is used as a measure of length only for measuring cloth, just as the aune is used in France. The other English measures

7. The metric system is now the standard with chemists, physicists and scientists all over the world, and it is generally conceded that for the work of the scientist the system is far superior to any other in use. The scientist uses it for weighing, measuring and calculating, which is precisely what machine constructors use it for, and there is no valid evidence to show that a system of weights and measures which scientists find most convenient would not be equally so for all other users of it.

8. For civil engineers or land surveyors, who now preferably use decimal sub-divisions, the metre forms an excellent base, replacing rods, chains, etc., and a convenient series of reduction scales can be derived from it, whereby dimensions on drawings can be readily interpreted by the standard scale. As the weight per unit of volume is derived directly from the specific gravity, the system facilitates the computations of masses of materials.

9. For all ordinary mechanical drawings the millimetre is well adapted, rarely requiring the use of decimal or fractional figures, and as no symbols for unit measure are needed, the chance for misinterpretation or error is less than with our system, where feet may be confused with inches and vice versa. Like-

of length, which are frequently cited by metric advocates, are either obsolete, obsolescent, or used by a very limited number of people for special purposes.

7. "The metric system is now the standard with chemists and scientists all over the world," because the chemists have found it convenient for their purposes. This is no reason why machinists should adopt it when it is inconvenient for their purposes. As for scientists using the metric system, this can only be true by giving a very limited definition to the word "scientist." The finest scientific work in refined measurements that has ever been done has been done in the machine shops of England and the United States, and has been done mostly in the English system. The statement that "there is no evidence to show that a system of weights and measures which scientists find most convenient would not be equally so for all other users of it," is opposed to the opinion of the largest users of measuring instruments in the country.

8. For civil engineers or land surveyors, who preferably use decimal sub-divisions, the foot now forms a perfectly satisfactory basis, replacing rods, chains, etc., and a convenient series of reduction scales (such as ¼ inch to the foot) can be derived from it whereby dimensions on drawings may be readily interpreted, thus obviating the necessity of translating existing records of land surveys into units which are entirely incommensurable with our present units. This fact is most forcibly shown in the provisions of the bill before Congress, which specially exempts the public land surveys from its operation. As to the weight per unit of volume being derived directly from the specific gravity, this necessitates references to tables of specific gravities of substances, which is no more easy than references to tables of weights per cubic foot and per cubic inch, as is customary. In fact, weights per cubic foot are usually more easily carried in the mind than specific gravities—for instance, cast iron, weight 450 lbs., sp. gr. 7.218; wrought iron 450 lbs., sp. gr. 7.7; brick 100 to 125 lbs., sp. gr. 1.6 to 2; gravel 100 to 120 lbs., sp. gr. 1.6 to 1.92; sand 90 to 110 lbs., sp. gr. 1.44 to 1.76.

9. For all ordinary mechanical drawings the inch is better adapted than the millimetre; the inch can be used up to more than 100 inches and down to any fraction, binary or decimal, that may be desired, and no symbols for unit measure are needed if the drawing states that all measures are in inches. The use

wise less figures are usually required than with our system, especially where many fractional terms are employed. The misplacing of a decimal point one place makes the result either ten times too large or too small, and such an error is usually instantly detected. If errors should arise from this source, adherence to a few simple rules will avoid them. In Europe the millimetre is usually the only unit employed in mechanical drawings and in machine shops.

10. That the system is superior to ours for fine tool-work is demonstrated by the fact of its adoption by so many manufacturers of this class here, especially such as produce optical instruments, watches, etc.

11. A convenient and expressive series of wire gauge numbers can be derived from the system, expressed in tenths of millimetres, using only two figures and the gauge numbers expressing the actual dimensions.

12. Its use would avoid the mixture of decimal and binary fractions now in common use in machine shops, and which require frequent conversion to decimal equivalents or reference to printed tables. For instance, it would entirely avoid such problems as the following: A hole is $1\frac{3}{32}$ inches diameter, a piece is to be turned to fit it with .003 inch clearance; what is the diameter of the latter piece? By reference to a table we find $1\frac{3}{32}$ inches = 1.09375 inches, and subtracting .003 inch we have 1.09075 inches. A parallel example in the metric system would be: Hole 29 millimetres diameter; diameter of pin to fit with .06 millimetres clearance equals 28.94 millimetres, and the size is thus obtained immediately, without a table and by mental calculation. In

on a drawing of both feet and inches is entirely a matter of choice with the draftsman or his employer. The statement that "less figures are required on an average than with our system" has frequently been denied by the heads of the largest shops in the country where both systems have been used. See paper by Dr. Coleman Sellers (vol. i., *Transactions*, A. S. M. E., p. 12); he says:

"My experience covers many examples of engineers and draftsmen educated in metric-using countries, who, when they come to us, learn to use our measures as quickly as we can learn to use theirs, but adopt our methods of calculation as involving fewer figures."

The use of the millimetre as the unit tends, on account of its small size, to increase the number of the figures required in a drawing.

10. The production of optical instruments and watches is an exceedingly small branch of manufacture, as compared with that of machine tools, and it may be convenient to use the centimetre or millimetre in such work, while the manufacturers of other tools would find it preferable to use the inch. Also, if the optical instrument makers and watch makers have voluntarily adopted the metric system, it is no reason why other manufacturers should be forced to adopt it against their will.

11. The use of wire gauge numbers is now generally condemned and is gradually being abolished, thousandths of an inch being substituted. For electrical wiring calculations the new unit, the circular mil, has been found to be a great convenience. The introduction of a new system of wire gauge numbers, the dimensions being in tenths of a millimetre, would be a deplorable addition to the existing confusion of wire gauges.

12. The English system avoids the use of decimal and binary fractions whenever the designer or user of the unit chooses to use either one fraction or the other in his work. For instance, a superintendent of a machine shop wishing to order a pin to fit a hole which is $1\frac{3}{32}$ diameter with .003 of an inch clearance, would, by reference to a table on his desk, or to the table stamped on his micrometer caliper, obtain the diameter of the hole in decimals, viz., 1.094, and the dimension $1.091 = 1.094 - .003$ would be given to the workman, or a gauge would be furnished him to work with. In other words, absolute dimensions for fine fits can be expressed in one unit just as well as in the other.

other words, absolute dimensions for fine fits can be expressed clearly and with greater precision than is the case with our system, and much figuring in shop and drafting room thereby saved.

13. Metric micrometers are graduated to read to .01 millimetre, and all such problems as the foregoing would be readily solved by draftsmen and workmen usually without the use of the pencil, and always without reference to a printed table. Furthermore, .01 millimetre is a better unit than .001 inch for micrometer calipers, because the former is somewhat less than one-half the magnitude of the latter and .001 inch is too large a unit for the better class of work done in machine shops, as is evidenced by the frequent necessity for dividing the .001 inch and reading measurements by estimation between graduations on the micrometer.

14. The system is so simple that the average workman has no difficulty in learning to apply it in a very short time (see pages 522 to 528 of accompanying discussion.) The metric hand-rule with the millimetre sub-division presents the most convenient minimum sub-division that can be devised. The $\frac{1}{16}$ inch on our hand-rule is too large, whereas the half of this, or $\frac{1}{32}$ inch, is found too small to be clear and legible for ordinary hand-rules. The system avoids the use of our common fractions, which are cumbrous and inconvenient.

15. In applying the standard scale for measurements the user is not hampered by preserving the distinctions between inches, feet, etc., or referring to the corresponding symbols. The measurement is simply read off and the terms referred to in any subdivision of the metre that is convenient and desirable, just as we do in reading our Arabic numerals, and the significance of these is readily grasped by those of the most ordinary intelligence.

16. The use of the metric system would not require the alteration of established standards, such as bolt or pipe threads, taper shanks of drills, etc. In fact, in many standard articles dimensions are only nominal and not real. In all such cases integral metric figures could readily be applied to these, which would be at least as near as the existing nominal dimensions are to the actual, but no change of actual dimensions would be required, and for ordinary use such standard articles would probably retain their present names or designations. No law could prevent this.

13. If the micrometer reading to .01 millimetre is better than one reading to .001 inch, so also is one reading to .0001 of an inch better than the one reading to .01 millimetre, and such micrometers are in daily use in tool-rooms on work requiring this degree of refinement.

14. The average workman in using the metric system has a more inconvenient rule to handle than the English two-foot rule, the former requiring sub-division by tenths, if the metre is used, while the latter is usually divided into four parts. The ordinary two-foot rule often contains on one side tenths of an inch, and on the other side sixteenths. If twenty-fifths of an inch were wanted, they would be put on it, but the average workman finds no difficulty in splitting the sixteenths by his eye, and reading by thirty-seconds. On steel scales sixty-fourths of an inch are quite legible.

15. In applying the standard two-foot rule, the user deals only with inches, unless he chooses to use feet. The choice of the two units is a great convenience, and he should not be deprived of it, since it presents a simple picture to the mind for mental conception of the required or existing dimensions.

16. The statement that "the use of the metric system would not require any alteration of established standards" can only be true by giving a very limited definition to the word "use." If the United States is to adopt the metric system it will have to adopt metric standards; that is, we would have a standard size of mandrel, whose dimension is 25 millimetres, for the manufacture of new machines, and we would also have a standard one inch mandrel, which we might call 25.4 millimetres, for repair work on old machines. But if the word "use" means simply that we are to continue to work with existing standards, and

17. The expense and confusion incident to making the change are usually much overrated, as it is now known by actual experience that the two systems can be used concurrently with little confusion in the same establishment (see pages 522, 523, 525 and 528 of accompanying discussion). Any changes of dimensions that might be desired for expression in integral metric units could be effected from time to time as the opportunity offered. All shops are constantly wearing out or renewing tools, gauges, etc., and at the proper time these can be replaced to conform in absolute dimensions to the metric units. The weight of evidence on record indicates that the change is actually made with less trouble and expense than is anticipated by those who oppose the system.

merely call them the metric names, we submit that this is not either the adoption or the use of the metric system, and it simply introduces unneccesary complication and confusion to attempt to express an existing standard dimension, which is exact in the English system, in terms of the metric system, with which the English system is incommensurable.

"In all such cases integral metric figures could readily be applied to these (standard articles), which would be at least as near as the existing nominal dimensions are to the actual, but no change of actual dimensions would be required."

In the case of a one-inch mandrel, would it be right to call it a 25-millimetre mandrel, when its true dimension is 25.4, and when there is also another 25-millimetre mandrel made to the French standard kept in the same tool-room? So also would the two-inch mandrel be called a 50-millimetre mandrel, or a 51-millimetre mandrel, which is the nearest integral figure? In regard to bolt or pipe threads, taper shanks of drills, etc., which are referred to, these are standardized to the .001 of an inch. In such cases integral millimetre figures could not properly be applied to them.

17. "The expense and confusion incident to making the change are usually much overrated." This statement can only be met by a positive denial. It is the overwhelming testimony of the largest manufacturers in the country, that the expense and confusion of making a change cannot be stated sufficiently strong.

Mr. Halsey says: "The man who can estimate or indicate in words the value of mechanical standards to this country and the loss due to their destruction, does not live. . . . The cost of attempting to change air-brake hose couplings is not represented by the value of the tools for making the couplings in the Westinghouse works, but by the infinite confusion of the railroads in getting from one standard to another. The value of the tools in this case is not many dollars, but the cost of the change cannot be found upon any inventory, nor can it be measured by any scale."

"Similarly again, the cost of changing our pipe-thread standard is not represented by the cost of new taps and dies, but by the confusion involved in getting from one standard to another—a confusion which will last until existing steam, water, and gas-pipes have disappeared, and which will not be lessened by put-

18. To the public at large the system offers the advantages of definite and convenient units of weight and volume. The conversion from one unit to another of the same class being effected by a simple mental process, without calculation or reference to tables, or any severe tax on the memory. Its adoption would abolish the conflicting units of weight and volume now so prevalent, and would bring all our standards of weights and measures to a simple expressive basis. Its adoption would tend to abolish the pernicious practice of selling products by the "basket" or "box,". or other measures of unknown capacity, a practice which encourages fraud. This result seems to follow where the system has been adopted.

19. The testimony of those who have used both the metric and the English system of measurements in machine construction and in other industries is largely in favor of the metric system,

ting off the change until it is brought about 'at the suggestion and convenience of manufacturers.'" (Halsey, p. 443.)

"Any changes of dimensions that might be desired for expression in integral metric units could be effected from time to time as the opportunity offered."

For instance, when would the opportunity be afforded to change the shape and size of a milling cutter adapted to cut teeth of six pitch (that is, six teeth per inch of diameter) of a gear wheel to adapt it to any integral metric unit? Of the hundreds of thousands of matched gear wheels of standard diametral pitches which are now in use, how is it possible to reproduce these in any integral metric unit, or effect this transformation without tremendous confusion? When will the proper time come to abandon every one of these gears and replace them with others which "conform in absolute dimensions to the metric units? The same applies to all screw-thread standards, pipes, bolts, turned shaftings, etc., and all standard shop sizes.

18. The alleged ease of conversion from one unit to another (of weight and volume) exists only in reference to distilled water. For all other substances tables must be referred to to show either the specific gravity in the metric system, or weight per cubic foot or per cubic inch in the English system. To the public at large the English system offers the advantage of definite and convenient units of weight and volume. The cubic inch, cubic foot and cubic yard, are all that are needed to express volumes, and the pound is all that is needed to express weight. But the weight of any given volume of any large number of materials, except distilled water, cannot be memorized by any ordinary man, and he must refer to tables of weights or specific gravities to obtain the weight. "The adoption would tend to abolish the pernicious practice of selling products by the basket or box." This pernicious practice can be abolished at any time without adopting the metric system, by the simple expedient of selling all boxed or basketed goods by the pound, or else by enacting laws to prevent the use of fraudulent measures, or boxes or baskets which do not represent known measures of volume. Thus, let the law provide that a quart box of strawberries shall actually contain a quart, or a definite amount by weight.

19. The testimony of those who have used both systems is by no means entirely in favor of the metric system. There are many witnesses on the other side.

as shown at pages 522 to 528 and 579 of the accompanying discussion.*

---

* Since the discussion of Mr. Halsey's paper was closed, Mr. Miller, continuing his efforts to gather the testimony of those who in machine construction or mechanical engineering work have used both the English and the metric systems of measurement, has received letters expressing strong preference for the metric system from the following:

Chas. J. Koeler, of New York, born and educated in Germany, and with subsequent shop and other experience here and in Germany.

John Brashear, member of this Society. Maker of astronomical instruments.

E. A. Marsh, general superintendent of the American Waltham Watch Co.

Arthur Falkenau, member of this Society.

L. D. Burwell, of Cleveland.

Joseph B. Edwards, of Chicago.

August Hoffmann, of Chemnitz, Germany.

J. L. Barnes, of New York.

These men have been placed in positions enabling to draw comparisons based upon actual experience, and although an effort has been made to get the testimony of men having similar experience and who oppose the metric system, no such testimony has been presented.

Mr. Coleman Sellers, in 1880, after nearly 20 years of constant use of the metric system, says, "it is not so well adapted to the wants of machinists as the one now in use. . . . Its enforced introduction will do harm instead of good" (*Transactions*, A. S. M. E., vol i.).

The firm of Wm. Sellers & Co. about 1860 adopted the metric system in the manufacture of the Giffard injector, equipping a complete department of their works for that purpose. More than 40 years later, on February, 1903, Mr. William Sellers writes to one of the members of this committee:

"Mr. ———, as I happen to know, has never given the subject any broad investigation. Those who have, such as the mechanics of the country, are almost universally opposed to the use of the metric system. . . . I think it would be deplorable if this Society should lend itself to the further introduction of this system in this country."

Mr. John H. Ball, of Barcelona, Spain, writes (Mr. Halsey's paper, page 419):

"In regard to the change from English to metric measures, proposed in the United States and being agitated in England, it surely would be a great pity to throw deliberately away the uniformity at present reigning in these countries. After four and a half years in a professedly metric country the English system is still to me the easier, owing to the greater number of years of practice I have had with it. After some forty or more years of the metric system in this country the mixture is, after all these years, an abominable mixture still, and bids fair to continue so for many years to come."

Mr. Henry Hess, in a letter in the *American Machinist*, October 16, 1902, says:

"Some years since I was asked to sign a petition to Congress asking that the metric system of measurements be officially adopted as the legal American standard; in common with many others I complied, under the impression that the ease of reckoning with decimals and the convenience of a logically harmonious system would be sufficient to compensate for all troubles, fancied or real, incidental to the change. Since then actual experience with the metric system has led to a revision of views. . . . The decimal system is only in part more convenient than a binary system, but not wholly so, or even more so. It is in fact more uncertain in arithmetical operations than the decidedly faulty

English system. This statement, directly opposed to my preconceived notions of a few years ago, is advanced as a result of direct experience with the metric system, extending now over three years. Having been gradually led to this conclusion, I determined to put it to a practical test. A certain problem—not made up specially for the occasion, but cropping up in regular practice—was submitted to seven draftsmen and designers, some of them of more than average attainments and all of them thoroughly familiar with the metric system through having used it almost exclusively in their practice and schooling. The correct result was arrived at by only three of the seven men.

"The problem was at first given to but one man, and only the obviously wrong result led to its being handed over to others. The difficulty lay in the correct location of the decimal point; with one exception all had the correct numerals, but the men were apparently lost in the maze of decimal figures. The location of the decimal point varied by as much as six places.

"The same problem with equivalent values in English units was then handed out. The correct result was arrived at by six out of seven men in an average of two-thirds the time taken for its solution in the metric system, showing that the percentage of error was very much less and the time considerably less with the binary system, notwithstanding the relative unfamiliarity of the men with the units of the binary system.

"From the draftsman's point of view, the binary system is also decidedly more convenient. In mechanical engineering practically the world over the most generally used scale is smaller than one-half. With the metric system the next one available to one-half is one-fifth; this is small and not convenient as compared with one-fourth; going further, the inconvenience becomes greater with one-tenth than with one-eighth, etc. Actual use will convince anyone of the truth of this, as it has me, who confesses to having been very skeptical as to there being a practically noticeable difference in convenience of quarter against fifth and eighth as against tenth scales."

Mr. Halsey, in his paper, page 411, quotes from a letter he received from an American engineer who has lived in Paris since 1889:

"The decimal division and multiplication of the metric system do not appear to suit various industries for widely different reasons."

20. The standard terms for metric measures can be readily abbreviated into terse words or monosyllables, adapted for popular use, but retaining the significance of the original. The adoption of the metric system would not involve much recalculation for standard technical tables, etc., as the French and German technical literature of this kind is quite complete, and it would be merely necessary to reprint their tables.

Mr. H. L. Des Anges (Mr. Halsey's paper, page 535), says:

"My experience with the metric system dates from early childhood and first school training, when I had a thorough knowledge of it. A change from the present system of measurement in my mind would work great hardship on the common run of engineers."

See also the opinions of several others who have used and are thoroughly familiar with the metric system, quoted in Mr. Halsey's paper—viz., J. H. Linnard, page 449; A. M. Mattice, page 515; Leon Von Muralt, page 515; W. E. Reed, page 516; Otto C. Reyman, page 516; J. E. Shore, page 536.

In a discussion before the Institution of Electrical Engineers (*Engineering*, London, February 13, 1903), Mr. Thomas Parker said "he had given thirty years of study to the metric system, and for four years had used it practically, and had found the units unsatisfactory and imperfect." Mr. Leslie Robertson said that "it had been his privilege to work in countries using the metric system. . . ." He thought that "the Institution ought to proceed with very great caution before it expressed an official opinion in favor of the metric system." Sir John Wolfe Barry said he was "bold enough to admit that he was averse to the metre as a unit, and to decimals for calculations. . . ." He had found the metre "too large for purposes of calculation and not so convenient as a foot."

20. "The standard terms for metric measures can be readily abbreviated into short monosyllables, adapted for popular use, but retaining the significance of the original." But the French people in a hundred years have not adopted such short terms! Can any terms be better than our foot or mile?

"The adoption of the metric system would not involve much recalculation for technical tables, etc., as the French and German technical literature of this kind is quite complete, and it would be merely necessary to reprint their tables." Will the writer of this sentence kindly exemplify it by producing a table which corresponds to the table of lap-welded pipe which is issued by all the pipe manufacturers of this country? Or, will he furnish a table showing the flow of water or steam in pipes of the existing American standard dimensions? Other examples might be suggested. Or, will he furnish a few sample tables which show in any way that his opinion on this subject is correct? The substitution of the tables in French and German technical books for

21. With the metric system the necessity of binary division largely disappears. Halving and quartering might be used as popular expressions, but the decimal fractions only would be used in technical literature. Binary divisions may, however, be used, as they sometimes are with our coinage.

22. It is generally acknowledged that if our existing systems of weights and measures should be retained indefinitely they should be entirely revised and codified to remove the existing inconsistencies and conflictions. The disturbance necessary to accomplish this result would go far toward giving us a coherent and logical system that would be in accord with that of the rest of the world. It is almost certain that the system is annually gaining strength, both here and in Great Britain and the British

those in English books will only be possible when all our standard sizes are the same as the French and German standard sizes —that is, when we no longer have pipes, bolts, etc., of even inches and binary fractions of an inch, but have pipes which increase in size (nominal diameters) by two to ten millimetres per size. [See The Metric System—a big job for a literary engineer —Appendix IX., p. 691.]

21. The binary division could be dispensed with also in the English system, if it were thought advisable, which it is not. A dimension of $1\frac{1}{16}$ inch gives a clearer mental conception than its equivalents, 1.0625 inches and 41.3 millimetres. It is inadvisable also to have the expressions in technical literature different from those in common use, as much of our modern technical literature is written for the ordinary workman.

Mr. William Sellers, in a paper published by him in 1902, says, in reference to one of the advantages of the binary as compared with the decimal system:

"It is desirable that all drawings should be as large as they can conveniently be made or read. . . . Therefore a scale or proportion of the full size must be used, as $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{6}$, $\frac{1}{6}$, $\frac{1}{8}$, $\frac{1}{10}$, $\frac{1}{12}$, $\frac{1}{16}$, to which the divisions of an inch on our rules are conveniently adapted. The $\frac{1}{8}$ size is very common, but the $\frac{1}{12}$ and $\frac{1}{16}$ are so small that they are seldom used. The metre with its decimal divisions affords no such facility; we are therefore confined to the $\frac{1}{2}$, $\frac{1}{5}$, $\frac{1}{10}$, $\frac{1}{20}$, $\frac{1}{50}$ of the full size, so that we have but three practical scales in the metric system, where within the same practical limits the inch base affords seven. The scale series most common upon the inch base is that of $\frac{1}{2}$, $\frac{1}{4}$ and $\frac{1}{8}$; this halves down from whole size, and can be raised in rapid drawing, by taking off dimensions with the dividers and doubling them, and by using diameter sizes from one drawing as radius dimensions in the other, a process impossible between the $\frac{1}{2}$ and $\frac{1}{5}$ sizes of the metrical scale."

22. "It is generally acknowledged that if our existing systems of weights and measures are to be retained indefinitely they should be entirely revised and codified to remove the existing inconsistencies and conflictions." We are glad to agree with this statement. It would be a good thing if the British Parliament and the United States Congress should pass a law defining the terms used in the English system, so that no two units differing in dimension should have the same name. The following is sug-

Colonies. The evidence obtainable seems to point that way. The resolutions of technical and trade associations and the foothold it now has before legislative bodies indicate this; and it seems not improbable that Great Britain may anticipate us in the adoption of the system.

gested as a system which would be as satisfactory as any that can be named based on the English inch.

Length: mil, inch, foot, yard, mile—5 units. (The yard to be commonly used for textiles only).
Surface: circular mil (for wire only), square inch, square foot, square yard, square mile.
Land measure: length, feet and decimals, area, square feet and decimals, acre, square mile. (The acre not because it is a good unit, but because it cannot be got rid of, as is evidenced by the provision of the exemption of land surveys in the Bill H. R. 2054.)
Volume: cubic inch, cubic foot, cubic yard (hundred cubic feet would be a better unit than cubic yard); new bushel = 1 cubic foot; new gallon = 6 inches cubed = $\frac{1}{8}$ cubic foot = 216 cubic inches; new quart = 54 cubic inches; new pint = 27 cubic inches = 3 inches cubed.
Weight: grain, ounce, pound, ton (2,000 pounds.); 1 new gallon of water at 52° F. = 7.8 pounds; 1 new gallon of water at 39° F. = 7.803 pounds.

"It is almost certain that the [metric] system is annually gaining strength, both here and in Great Britain and the British Colonies." Against the growing strength of *opinion* as shown by resolutions, etc. in favor of the metric system we have to show the far greater growth of *practice* with the English system, due to the rapid growth of population, wealth and industrial pursuits in English-speaking nations, the building of railroads, shops, etc., the general tendency to standardization of sizes (based upon the inch) of articles of manufacture and the tools for making them; the spread of technical education, correspondence schools, etc., and the ever-increasing mass of technical literature based upon English standards.

"It seems not improbable that Great Britain may anticipate us in the adoption of the system." The metric system was formally legalized by Great Britain in 1864 and by the United States in 1866. A British Royal Commission, appointed in 1866 to consider the subject of weights and measures, presented five reports between 1868 and 1871. The second report recommended the substitution of the metric for the Troy weight in the mint, its permissive use in customs and other places, and its gen-

23. The retention of ancient units of measurement in popular phraseology, or in exceptional industries, has no force as an argument against the metric system, as this merely illustrates a well known trait of mankind, where tradition or force of habit tends to maintain ancient or obsolete terms or usages in a rudimentary form. This was exemplified with our monetary units. Ancient and objectional units remained in use for a generation after the adoption of our decimal currency. Roman numerals are still retained on watch faces, title pages of books, etc. The Gregorian calendar has not yet entirely displaced the Julian calendar, throughout the civilized world. Yet no one could effectively maintain that the abandonment of these ancient systems was unnecessary and effected no useful purpose. On this phase of the subject see remarks of President Pritchett, of the Massachusetts Institution of Technology, at pages 488 to 491 of accompanying discussion.

JAMES CHRISTIE,
FRED J. MILLER.

It had been at first thought that the above presentation, with the accompanying paper and discussion would be sufficient, but the anti-metric wing of the committee preferred to make an affirmative statement of its side of the question. This statement eral encouragement, but that in no case should compulsion be used, believing that the owners of factories and others who might desire to use it could arrange such matters without legislative assistance. (George W. Colles, *Transactions*, A. S. M. E., vol. xviii., page 527).

This is as far as Great Britain has as yet gone toward the "adoption" of the system. The Weights and Measures Consolidation Act of 1878 reaffirmed the existing standards, again making the metric weights and measures permissive. If "adoption" means compulsory enforcement, then Great Britain is a long way from the adoption of the metric system. That this country will ever "adopt" the system in this sense, whether anticipated or not, is doubted even by its advocates. "We do not believe that Congress can by law invade the rights of the people to use any system they may prefer, and do not believe that anyone thinks of doing such a thing" (Section 10 of our opponents' reply to our argument, p. 679)..

23. "The retention of ancient units of measurement in popular phraseology . . . has no force as an argument against the metric system." Possibly it is not an argument against the system *per se*, but the "well-known trait of mankind, where tradition or force of habit tends to maintain ancient or obsolete terms" is a powerful obstruction to the general introduction of the system, and it may be used as an argument to show why the people of the United States are no more likely to adopt the metric system than they are to adopt the French language.

William Kent,
George M. Bond.

---

follows, and will be found on the left-hand pages, while the answers to the points made will be found upon the right-hand pages; corresponding numbers being used throughout for convenience.

Argument Against the Metric System.

I.

WHAT THE ENGLISH AND THE METRIC SYSTEMS ARE.

As preliminary to the arguments on the English *versus* the metric system, it may be well to state just what the English and metric systems are as used by the great bulk of the population in metric and non-metric countries.

The following is a table of the customary measures of length, surface, volume and weight in the two systems of measure. From this table have been omitted in both systems the dimensions that are not in general use:

COMPARATIVE ENGLISH AND METRIC MEASURES.

English	Metric
Length:	
Inch	Millimetre — 0.03937 in.
Foot	Centimetre— 0.3937 "
Yard	Decimetre — 3.937 "
Mile	Metre — 39.37 " ——3.28083 ft.
	Kilometre —3280.83 ft. ——0.62137 mile
Surface :	
Sq. inch	Sq. centimetre—.1550 sq. in.
Sq. foot	" decimetre —15.50 sq. in.—0.10764 sq. ft.
Sq. yard	" metre—10.764 sq. ft.—1.196 sq. yd.
Acre	" dekametre or are—1076.4 sq. ft.—119.6 sq. yd.
Sq. mile	Hectare " 100 ares—107,639 sq. ft.—2.471 acres
Volume :	Sq. kilometre—247.1 acres—0.3861 sq. mile
Cu. inch	Cu. centimetre—millilitre— 0.0610 cu. inch
Cu. foot	Centilitre — 0.6102 "
Cu. yard	Decilitre — 6.1023 "
Quart	Litre—1 cu. decimetre — 61.023 "
	— 1.0567 quarts
Gallon	Hectolitre or decistere—3.531 cu. ft.
	—2.8375 bushels
Bushel	Decalitre or centistere—0.3531 cu. ft.
	—2.6417 gallons
	Stere, kilolitre or cu. metre—35.314 cu. ft.
	— 1.3079 cu. yds.

Replies to Argument Against the Metric System.

I.

The number of fundamental units for weights and measures used in either the British or the metric system has little, if any, bearing upon the respective merits or demerits of the two systems. The essential difference is, however, that in the British system the complex relationships of the various denominations are such that they are interconvertible only by calculation, whereas in the metric system no such calculation is required, as they are interconvertible by inspection; because the metric system as elsewhere expressed "harmonizes with the world's arithmetical notation."

The person who has learned to count general quantities as expressed by the numerals of the world's decimal notation, readily understands and retains in his memory its application to metric measures. When daily experience requires him to use the former, he cannot well forget the latter.

It is frequently observed that a large part of the community who are not habitually required to use our units of weights and measures, have no recollection of the relation between the units; for example, the number of feet in the mile or ounces in the pound, etc. This arises from the obscure or unequal relation existing between the denominational units of our system. In ordinary metric measurements, such as are used in machine construction, etc., it is neither necessary nor customary to name the units that are expressed numerically. The figures carry their own significance; for example, if a dimension is 1245 millimetres, the speaker usually says twelve-forty-five without any reference to the special unit intended, which is always understood, and the expression is as simple as when naming our binary fractions. Therefore in metric using countries it is claimed that abbreviations for utterance of the terms are not of much importance, as the terms themselves are so little used. This is in marked distinction to our system, wherein the terms have to be constantly employed to preserve the distinction between feet, inches, etc.

For the quantities cited above, one familiar with the system

Weight (avoirdupois).

Grain	Milligram—	0.01543 grain
Ounce	Decigram—	1.5432 "
Pound	Gramme —	15.432 "
Ton (2,000 lbs.)	Kilogram—	2.20462 pounds
	Tonne —	2204.62 "
		(1.10231 net tons)
Total English, 19.	Total Metric, 30.	

In the metric system there are seven fundamental units—*i. e.*, the metre, the square metre, the are, the cubic metre, the liter, the stere, and the gram. The sub-divisions are expressed by the seven prefixes, milli, centi, deci, for the smaller dimensions, and deca, hecto, kilo, myria for the larger dimensions.

The following table shows which of the 56 possible combinations of the prefixes and the base unit are in common use, those used being shown by a star, and those not used by a dash:

	Length	Surface		Volume			Weight
	metre	Sq. metre	are	Cu. metre	litre	stere	Gramme
Milli	*	–	–	–	*	–	*
Centi	*	*	–	*	*	*	*
Deci	*	*	–	*	*	*	*
Deka	–	*	–	–	*	–	–
Hecto	–	–	*	–	*	–	–
Kilo	*	*	–	–	*	–	*
Myria	–	–	–	–	–	–	Tonne
Out of eight use	5	5	2	3	7	3	5

Total 30 out of 56.

The above tables show that the English system has 19 units in common use. Nearly all of them are expressed in monosyllables, and everyone of them is familiar to every English-speaking school boy twelve years of age. Their values are definite. The metric terms are thirty in number, and nearly all of them are expressed in polysyllables.

II.

MANY OF THE ANCIENT ENGLISH MEASURES ARE OBSOLETE OR IN BUT LIMITED USE.

From the table of English measures have been omitted those measures that are either obsolete or obsolescent, and only used knows at a glance that the measurement is either 1245 millimetres, or 1 metre and 245 millimetres, or 1 metre, 2 decimetres and 45 millimetres, or 1 metre, 2 decimetres, 4 centimetres and 5 millimetres, if for any reason it is desired to so express the measurement, although this would be very unusual. Likewise if the same numerals express weight in grams, the reader knows as he reads that it means 1 kilogram, 2 hectograms, 4 decagrams, 5 grams. As the relations between the denominations are simple, clear and expressive, the small units of weight are more frequently used in the metric system by people of average intelligence than is customary with us. Ask any grocer how many of his customers can clearly comprehend quantities below ¼ of a pound? The smaller units of weight in our system are obscure to the great majority.

The misinterpretation of drawings by occasional confusion between feet and inches, is an old and never-ending source of trouble in our system. The attempt to obviate it by making all numerical terms on drawings in inches, has proved equally unsatisfactory, as when measurements of several feet are involved the workmen must make the conversion by calculation, thus introducing another source of possible error. This difficulty is absolutely avoided in the metric system. The clear and expressive significance of the numerical terms stands in marked contrast as much superior to our crude methods. An eminent opponent of the metric system says, "the English inch is a resting place for the memory." This is probably true when the mind has been struggling with our common fractions, relics of the unlettered age of mankind, the units not being interconvertible excepting by a process of calculation, and as the inch is the most familiar unit. But in the metric system every unit is a resting place for the memory, as ordinarily no interconversion is needed. The terms are simply read off and are clearly intelligible to anyone familiar with the numerical series of our standard notation. One knows that each term on the descending scale has one tenth the value of that preceding it.

II.

No matter what system may be used, any given industry or trade will employ only those units of measurement which are by a small fraction of the population engaged in special trades. Among those omitted are the chain, link and rod, which are never used except by some engineers in surveying old boundaries, the foót having generally taken their place; the furlong and the league, which are obsolete; the point and the line, which are used only by printers; the fathom, used by sailors; the hand, used by horse dealers, and the mil, used in electrical engineering work, being a thousandth part of an inch. From measures of surface have been omitted square rod and rood, which are obsolete, and the circular mil, used only in electrical wiring calculations. In measures of volume there are omitted the cord, used in measures of firewood only; the perch, used by masons; the gill, hogshead and barrel,* tierce, etc., which are practically obsolete measures of liquids. Also the pint, which is simply half a quart; and the peck, which is quarter of a bushel and only used by green grocers. The fluid drachm and fluid ounce are used only by druggists for liquid measures. In the tables of weights there are omitted drachms, quarters, hundred weight, stone, which are obsolete measures in the United States. The Troy and Apothecaries' Weights are omitted, with their pound, ounce, pennyweights, grains, scruples and drams, because Troy Weight is only used in measuring silver and gold, and Apothecaries' Weight only for prescriptions. So that the nineteen terms in the above tables are all that are really needed by the English-speaking races for all commercial and manufacturing purposes.

* Barrels and hogsheads are containing vessels like boxes and cans, and may vary considerably in capacity. The measure of a barrel given in the books, 31½ gallons, is not the measure of the capacity of barrels as they are now made.

III.

CONVENIENCE OF THE ENGLISH UNITS.

Now as to the relative dimensions of these units. The four measures of length are familiar to the English-speaking race the world over, and a mental conception is immediately formed whenever one of them is mentioned. The yard is practically obsolete for all purposes of linear measurement except in measurconvenient for its work, and will usually dispense with the others. It is, however, obviously an advantage to have all terms of measurement used by others readily convertible into the terms or units with which one is familiar by reason of daily use. This advantage is secured by the metric system and is not secured by the British system.

If, however, a fewer number of units is considered an advantage to a system of measurements, then the metric system will easily stand fair comparison with the British on that score. The comparison as made is most unfair to the metric system, especially so far as it applies to the machine-building industries, because, in machine construction, dimensions in whole numbers of inches are very rare, and in fairness the fractions $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$ and .001 inch should be added to the list of British units because all these are in common use in machine shops. On the other hand, .01 millimetre should be added to the list of metric units because it also is used in machine construction. When these additions have been made we find that in the English system there are nine different units commonly employed in machine construction and only two, or at most three, in the metric system.

In practice also, the square inch and the cubic inch have often to be divided into fractional parts; much more frequently so than the square centimetre and the cubic centimetre, because the former are much larger units.

What we would regard as a fair comparison therefore, would show very different results, but we do not consider this to be of sufficient importance to warrant our making another table.

The chain and the link are still commonly used in all farm surveys, the foot and the hundredth of the foot in city surveys and in levelling. These are used because surveyors and engineers find the decimally divided unit much more convenient both in field work and computation.

III.

Mental conceptions of the dimensions of units comes with experience in the use of any system, just as one learns to think in any language with which he is familiar. The mental conceptions, however, are more easily obtained and preserved with the metric system than with ours; as the denominations have a uniing cloth and yarn. The sizes of these units are entirely satisfactory, or at least they are more satisfactory for practical purposes than the metric units. As for square measures, the square inch, square foot, square yard and square mile, are entirely satisfactory units and much more satisfactory than the six units in the French metric system. The acre is not a satisfactory unit, and in course of time it may be abolished, its place being taken by some even multiple of the square foot, as already obtains in city land measurements.

As to the measures of volume, the cubic inch, foot and yard are really all that are necessary for a good system of measurement, but the quarts, gallons and bushels are convenient sizes used in commerce. The three units of weight, ounce, pound and ton, are entirely suitable for the ordinary uses of commerce. The grain is practically not used except in druggists' prescriptions. The objection to the different kinds of English tons is not an objection to the English system *per se;* at any time the ton of 2,000 pounds may be made the legal ton for buying and selling. For chemists' purposes the metric system is in common use and is entirely satisfactory, but for ordinary purposes of weights the English system is superior in having a smaller number of terms and in the sizes of units being more suitable for commercial uses.

The accurate or scientific measurement of the length of a bar or of a land boundary, may be done equally as well in the metric as in the English system. So the accurate weighing of a body of unknown weight may be done on a chemist's balance equally as well in one system as in the other.

But such measurements and weighing form an exceedingly small fraction of all the measurements and weighings done in commerce and the industrial arts. The more common measurement is to lay off a given dimension which is marked on a scale. Thus the carpenter with his two-foot rule lays off on a plank to be cut the dimensions 8 feet long by six inches wide; the iron roller makes bars 1 inch diameter, and cuts them off 16 or 20 feet long. The machinist measures the bar to find out whether it is 1 inch or the next size smaller, $\frac{15}{16}$ of an inch; he cuts off a piece of definite length, and turns it to a definite diameter which he sets on his calipers. The cloth manufacturer sets his loom to produce cloth 36 inches wide, and he cuts it off a given number of yards in length. The grocer does not weigh to find how form relation to each other and are expressed in numerical order. The difficulty of acquiring the mental conception referred to is frequently commented upon by those who have been accustomed to metric measurements and are unfamiliar with the British system. The complexity of the latter as compared to the simple, expressive metrology of the former is one of the reasons why the eminent physicist, Lord Kelvin, has characterized the British system as "a brain wearying, intellect destroying system." For the respective convenience of the two systems see pages 522 to 528 of the accompanying discussion from those who have used both systems, particularly the testimony of Sir Benjamin Baker, at bottom of page 525.

many pounds, ounces and grains there are in a certain bulk of sugar, but he weighs out so many pounds. The druggist weighs out so many ounces, or a half, quarter, or eighth ounce. For all such measurements and weighings, which constitute probably nine-tenths of all the measurements and weighings in the world, the English units are superior to the metric units, and the binary system of sub-division is superior to the decimal. The foot and inch are more convenient than the metre and its decimal subdivisions, and the binary system of division is so necessary for the needs of the common people that it is quite commonly used in metric countries.

If a man wants to divide a metre into any other binary division than halves, quarters and eighths, he cannot do it on a metre scale without splitting a millimetre and making an approximate measurement, while on an English scale he can divide a foot into thirds, sixths, twelfths and twenty-fourths, as well as into binary divisions as far as 64ths (if the scale reads to $\frac{1}{16}$ of an inch), and he can divide an inch on a machinist's steel scale as far as $\frac{1}{64}$ of an inch.

IV.

THE ENGLISH-SPEAKING PEOPLE THINK IN THE ENGLISH SYSTEM.

A serious objection, in our opinion, to the introduction of the metric system is that all the English-speaking race think in the English system. The attempt to make these people do their thinking in the metric system would be the work of at least two generations, during which time there would be endless confusion and an enormous waste of mental effort in trying to keep the two systems side by side. All the literature in mechanical science and engineering in the English language, which has accumulated in the past one hundred years, would be practically unreadable until translated into the new system, if people are compelled to do their thinking in the metric system. In the expressed opinion of business men of great experience in manufactures it would retard the development of the manufactures of the United States at least twenty-five years, and be practically at the cost to the country of their present prestige. Let anyone take one of the engineers' pocket-books and attempt to re-write a few pages of it, especially those involving formulæ, such as the formulæ for

IV.

There is no foundation for the assertion that it would take at least two generations for the English-speaking race to learn to think in the metric system. It was accomplished in Germany within a few years, and we have many illustrations of a similar character; for example, our own change of currency, the change to a decimal currency in Canada, which was made with hardly a ripple of disturbance. The printers have changed their entire system of type measurements without confusion, and other instances could be cited. The mere fact that the use of ancient terms and units continues in certain industries, or in communities isolated in thought and habit from the major ranks of society, carries no more weight than does the fact that we still retain Roman numerals on our watch faces, etc.

A large number of the articles enumerated would require no immediate change other than that of name, until such time as they may be superseded by new tools or articles of the desired absolute dimensions. Old tools and appliances are continually flow of water and flow of steam, expressing all the units in the French system, and then show the result to a friend, and ask him to form the mental conception of the dimensions therein expressed, and he will get a realization of the enormous amount of effort needed to change the reference books into the French metric measures, and the still greater effort to comprehend them after they are so changed. (See "A Big Job for a Literary Engineer"—Appendix IX., page 691).

A recent writer on this subject mentions a man whose height is 1.87 metres in his stocking feet, who has a girth around the chest of 1.18 metres, and weighs 90 kilograms. Do these figures convey any conception of the size and proportion of this man to the readers of this statement?

V.

THE ENGLISH SYSTEM IN THE MACHINE SHOP.

The whole literature of mechanical science and industrial art in the English language contains the inch as the basis of measurement of length, surface and volume. Also in Great Britain and the United States, for all ordinary purposes,* there are based on the English inch:

All rules, tables and formulæ used in calculations involving measures of length. All drawings of manufactured articles. All measuring scales and measuring tools, calipers, verniers, etc. All drills, taps, reamers, screw-threads, boring bars, milling cutters, mandrels, standard plugs and rings, and shop tools, gauges, templets, etc., that are based on this standard unit. All machine tools, leading screws of lathes, and feed and elevating screws of milling machines, planer heads, etc. All graduated heads of feeding screws. All interchangeable parts of the things made in machine shops, which things are distributed all over the world. All gear wheels, gear cutters and gear patterns. All

* We may except from this statement watch tool and optical instrument shops, the engine works of Willans & Robinson in England, and the injector shop of Wm. Sellers & Co. in this country, but the exceptions to the rule are as 1 to 100,000 and prove the rule.

being displaced by new, and now more rapidly than at any previous period.

The opposing argument, illustrating the supposed difficulties involved in the change of system, cites the case of standard tubes and tables for flow of fluids. In reply it can be confidently asserted that integral metric units can be applied to both external and internal diameters of our standard tubes, which are at least as close, if not closer, to the actual dimensions than those given on our tables, and for the flow of fluids our terms have merely to be translated to the metric measures.

This whole argument, it seems to us, is largely a case of imagined difficulties; difficulties which it is almost universally declared by those who have tried the metric system in actual work do not exist, or are much less serious than one who has made no trial of it is apt to imagine.

V.

On this point we can do no better than again to refer to the testimony of Sir Benjamin Baker at page 525. It is evident that he has failed to discover the difficulties named or that he has found it very easy to overcome them. See the testimony of the great engine builders at Rugby, England, on this point, at page 522 of the accompanying discussion, also the testimony of Mr. Arthur Greenwood, of the great tool and general engineering firm of Greenwood & Batley, at page 525 of accompanying discussion.

Several years ago a Phildelphia machinist, Mr. A. Falkenau, a member of this society, built a gas engine from French drawings, on which dimensions were given in millimetres. He procured metric scales and gave them to his workmen, who in a few days were entirely familiar with the measurements and followed the drawings without any hesitation or difficulty. He states that he expected difficulties which did not manifest themselves.

The British system is satisfactory to those who have been given no opportunity to familiarize themselves with a better. Its use, like many other objectionable habits, has been imposed upon us by inheritance, and it can be eradicated only by an effort.

pulleys and shafting, hangers, couplings, bushings and bearings. All merchant sizes of bars and plates of iron, steel and other metals. All structural iron shapes. All merchant sizes of pipe, pipe flanges, pipe fittings, valves, and the screw-threads of the same. All bolts, nuts, rivets, keys. Locomotives, cars, railroads and their appurtenances, all marine and stationary engines, all ships. All parts kept in stock for repair or replacement of these things.

As to the number of these things in use throughout the world, produced by the shops of the United States and Great Britain, they are more than the similar things produced based on all other systems of measurement in all the rest of the world combined. As to the number of people engaged in making these things in the United States and Great Britain, they are more than the number of people engaged in making similar things in all the rest of the world combined. As to the number of people using these things throughout the world, they comprise more, also, than those who use similar things based on all other systems of measurement combined.

Every Anglo-Saxon mechanic and draftsman in the United States and Great Britain (in watch and optical instrument factories possibly excepted) *thinks* in the English system of measurement. The common people in these countries universally think in that system. To the English-speaking mechanic the English system is a perfectly satisfactory one. Every technical paper and book he reads or refers to uses that system. For him to change from one system to another would be worse than for him to learn a new shop language. He might with much effort learn a thousand new words, and accustom himself to use them instead of their English equivalents, but in his use of the metric system he would have to compute either mentally or on paper every time he had to compare a measurement in English with one in the French system, or vice versa. If he were given a metric measurement he would have to translate it into English to get a clear mental conception of it. If the metric system were adopted in this country, the next two generations of mechanics would have to learn both systems, and to think in both.

Mr. Coleman Sellers in 1880 (*Transactions*, A. S. M. E., vol. i.) said: "The (metric) system *per se* is not as well adapted to the wants of machinists as the one now in use. . . . Its enforced introduction will do harm in place of doing good.

We respectfully submit that a practical trial is the only way by which reliable evidence in such matters can be secured. The people to whose evidence we refer have made such trials, and therefore know what they are talking about. They could have no possible object in misrepresenting the facts as they have found them, nor in deceiving others in regard to them, even if they were men who were capable of consciously doing such a thing.

"After nearly 20 years of constant use of the metric system, I record my opposition to any enforcing legislation in this direction." "The resting place for memory in the American system of shop sizes is the inch."

"One of our tool-room keepers reports the names of 129 articles or sets of articles used in producing one size—viz., 1¼ inch. . . . Drills, reamers, gauges, boring bars and cutters, taps of all kinds for all sorts of uses, hardened mandrels, these pieces costing many hundreds of dollars for one size only. They tally with and belong to the dimensions marked 1¼ inch in many thousand places on drawings which have been accumulating for years, to patterns, to gear wheels, interchangeable over a continent, and to the output of our factory for years. The question is not shall we change from the English to the metric system, but shall we attempt to have two systems side by side, with the resulting confusion?"

VI.

THE VALUE OF OUR ENGLISH STANDARDS.

Mr. F. A. Halsey (page 38 of his recent paper) says: "The abandonment of the inch will involve the destruction of our existing standards. . . . The chief value of a standard lies in the fact that it is adopted, that it has become part of our daily lives. . . . Because the threads are standardized, pipe fittings can be made by the million, at trifling cost, and that when we need a fitting we can buy it for a few cents with the assurance that it will fit instead of having to get it cut to order to suit an odd size of thread." (See also Appendix No. 12, p. 699, answer to question 9 by the Cincinnati manufacturers, *American Machinist*, November 27, 1902).

VII.

THE SIMPLICITY OF THE ENGLISH SYSTEM.

The fundamental and universal units in the system are:

Length.	Surface.	Volume.	Weight.
inch	sq. inch	cu. inch	grain
foot	sq. foot	cu. foot	ounce
yard	sq. yard	cu. yard	pound
mile	sq. mile		ton (2,240 lbs.)

These are all the units that need be used in computations by the mechanic and engineer, fifteen in all.

The number of these units may easily be reduced, for mechanics and engineers scarcely ever use the yard or the square yard. The cubic yard is used as a measure of earth and rock, by old usage, but a new unit of 100 cubic feet might with advantage be substituted for it. So also the ounce and grain might be abandoned and decimal sub-divisions of a pound used instead.

The mechanic and engineer would then have only nine fundamental units to memorize—viz., *inch*, *foot*, *mile*, *square inch*, *square foot*, *cubic inch*, *cubic foot*, *pound*, *ton*.

The nine units form a system superior in every way to the metric system. Any one of them may be used with binary or decimal sub-divisions as desired. The inch is a more convenient unit than the millimetre for the mechanic and the draftsman. The foot may conveniently be used by the engineer for any distance from .001 foot to several thousand feet, and the mile being used only for long distances as on roads or on the sea. The square foot may be used for large as well as for small areas as we speak of a floor or land area of 20,000 square feet. The cubic foot is a most useful unit both for solids and liquids. The names of all these units are monosyllables, and differ greatly in sound, while those of the metric system are mostly polysyllables, many of them similar in sound, and are derived from Greek and Latin. A few other units may conveniently be used for certain purposes, such as the mil (.001 inch) and the circular mil for electrical wiring calculations, and the acre or $\frac{1}{640}$ of a square mile, since it is "irrevocably tied to the past" in our land surveys. The importance of retaining our existing measures of land is recognized in the bill now before Congress.

VII.

Commenting upon the alleged simplicity of the British system, our confreres again omit to add the six usual binary divisions of the inch, from $\frac{1}{2}$ to $\frac{1}{64}$ inch inclusive, which are practically all independent units, and in the metric system are replaced by the single unit, the millimetre, and its decimal division .01 millimetre. The mere assertion of superiority for these units is far from convincing to those who do not use them, or to those who have learned to dislike them.

The practically universal testimony of those who have used both the metric and the English systems is that the former is very much the more simple and convenient in every way.

We prefer to take the testimony of those whose opinions are based upon actual experience with both systems and who are therefore in a position to draw comparisons based upon actual working knowledge of both systems.

Again we refer to such testimony at pages 522 to 528 of the accompanying discussion.

Certain other units will be retained, not because they are necessary, but because they are in universal use, such as the bushel, 2140.52 cubic inches, and its binary sub-divisions for measuring grain, and the gallon, 231 cubic inches, and its binary sub-divisions for measuring liquids.

There is no reason for the English system retaining the gallon and the bushel except that they are in such common use. For convenience of computation it would be well if the gallon were 216 cubic inches, or the cube of 6 inches, and the bushel 1,728 cubic inches, or 1 cubic foot.

The yard will necessarily be retained for measuring textile fabrics and yarns, because it is in use in the textile trades all over the world. Three-quarters of all the cloth sold in the world is sold by the yard. It is used in the manufacture of cloth even in France. The carat, a special unit for weighing diamonds and other precious stones, equals 3.168 grains, or 0.205 gramme, is in universal use all over the world, and no useful purpose would be served by abandoning it. Troy weight, ounces, pennyweights and grains is used only for weighing the precious metals, and Apothecaries' weight, ounces, drachms, scruples and grains (the ounce and the grain being the same in both, and the grain = $\frac{1}{7000}$ of an avoirdupois pound) is used by apothecaries and physicians for prescriptions only. Both Troy weight and Apothecaries' weight might be abandoned.

VIII.

SUPERIORITY OF THE ENGLISH SYSTEM.

The English system is *per se* a better system than the French in that it has

1. A smaller number of units (when the obsolescent units are discarded).

2. The dimensions of the units are more convenient for most purposes of measurement.

3. The binary sub-divisions are more convenient and more quickly comprehended by the ordinary mind than the decimal sub-divisions of the French system.

4. The names of the units are more easily memorized.

5. The two units of length, inch and foot, and the binary sub-divisions of the inch give a clearer mental picture to the average

VIII.

This again is a mere statement of opinion, which is by no means borne out by the testimony of those who by reason of experience are competent to give reliable testimony.

man than the numerous units, with their prefixes, milli, centi, deci, deca, hecto, kilo, myria, based upon the metre.

The English system has had centuries of use with no tendency to change the dimensions of the fundamental units, inch, foot, yard, and pound. The English foot and inch are fixed in existing measuring instruments, gauges, tools, patterns, machines, machine products, buildings, and fixed in the literature of the language for centuries. They are "irrevocably tied to the past."

IX.

INCREASING USE OF THE ENGLISH SYSTEM.

The people who use the English measures of length in manufacturing are more than those who use the metric measures. Their number is increasing more rapidly. The English race is increasing in numbers and in wealth at a greater rate than any other race. The Anglo-Saxons are the great colonizers. The use of their language is becoming more common throughout the world, its use is growing faster than that of any other language. The English language is more likely than any other to become the universal language of commerce, the one language which every educated person will have to learn. The English system of measurement is an indestructible part of the language.

X.

DIFFICULTY OF CHANGING FROM THE ENGLISH TO THE METRIC SYSTEM.

"The change of the method of measuring lengths from the foot and inch system to the metric system is utterly impracticable and visionary. If any body of law-makers such as our Congress should inflict such a burden upon the people without their consent, it would be the greatest invasion of the liberties of the people which has ever been attempted by a representative government."

"Yes, first establish an international money system, successfully accomplish the reform in the spelling of the English language, teach all the nations of the earth to speak one universal language, or do any other desirable but herculean labor which

IX.

This statement is not borne out by the records. It is quite certain that the metric system is fast gaining ground, and it is universally believed by those who have given the matter impartial consideration that the metric system is the only one that has the least chance of ever becoming universally used by all the nations of the earth.

X.

We do not believe that Congress can by law invade the rights of the people to use any system they may prefer, and do not believe that anyone thinks of doing such a thing.

As to the difficulty of making the change we must again refer to the testimony of those who have made the change and who say that it is not as difficult as usually imagined, and that it results in no serious disturbance or expense. See again the testimony of these people at pages 522 to 528 of the accompanying discussion.

The "transition period" referred to as a dreaded anticipation is already here, inasmuch as the metric system is now used in finds its chief hindrance in the habits, traditions and prejudices of millions of the human race, and you may be prepared to undertake such a revolution as would be the substitution of the metre for the two-foot rule." (Wm. Kent, *Transactions*, Engineers' Society of Western Pennsylvania, vol. i., 1880).

In conclusion, we desire to express our opinion in addition to the arguments submitted above, that in view of the testimony and experiences cited, the metric system with all its alleged advantages comes far short of meeting the requirements of a practical system for universal adoption; that intrinsically it is not as good as the English system; and that the exclusive adoption of it by the English-speaking race is impracticable.

WILLIAM KENT,
GEORGE M. BOND.

APPENDIX I.*

ADDITIONAL REPLY TO PARAGRAPH No. 16 OF THE PRO-METRIC ARGUMENT.

(*See page* 641.)

16. "The use of the metric system would not require the alteration of many established standards, such as bolt or pipe threads, taper shanks of drills, etc."

This statement requires some further consideration. In every machine shop in English speaking nations there are numerous tools, such as mandrels, drills, reamers, etc., made to standard sizes based upon binary divisions of the inch. These are verified as to size by reference to standard plugs, rings, gauges, etc., which are made accurate to $\frac{1}{10000}$ inch or less, and these, in the special shops in which they are made for the market, are verified by comparators with microscopic measurements. These standard tools are used in the production of millions of articles of standard size, which are interchangeable throughout the world. The adoption of the principle of interchangeability and duplication of parts has been one of the chief causes of the present leading position of American manufactures in the markets of the world. The principle has its foundation in standard gauges based on the English inch.

The principal standard sizes below 2 inches are the following, expressed in

---

* These appendices are contributed by the anti-metric half of the committee. The pro-metric reply to Appendix XII. is inserted immediately under it.

our scientific work, and a not inconsiderable part of the industrial work of both this country and England. It is more frequently used in our technical literature than formerly, without the addition of the corresponding terms in British units. These facts indicate that we have begun the adoption of the system.

JAMES CHRISTIE,
FRED J. MILLER.

---

inches and binary fractions and in the nearest metric dimensions to .01 millimetre :

in.	mm.	in.	mm.	in.	mm.
$\frac{1}{16}$ =	1.59	$\frac{9}{16}$ =	14.29	$1\frac{1}{8}$ =	28.58
$\frac{1}{8}$ =	3.18	$\frac{5}{8}$ =	15.88	$1\frac{1}{4}$ =	31.75
$\frac{3}{16}$ =	5.76	$\frac{11}{16}$ =	17.46	$1\frac{3}{8}$ =	34.93
$\frac{1}{4}$ =	6.35	$\frac{3}{4}$ =	19.05	$1\frac{1}{2}$ =	38.10
$\frac{5}{16}$ =	7.94	$\frac{13}{16}$ =	20.64	$1\frac{5}{8}$ =	41.28
$\frac{3}{8}$ =	9.53	$\frac{7}{8}$ =	22.23	$1\frac{3}{4}$ =	44.45
$\frac{7}{16}$ =	11.11	$\frac{15}{16}$ =	23.81	$1\frac{7}{8}$ =	47.63
$\frac{1}{2}$ =	12.70	1 =	25.40	2 =	50.80

No ordinary mechanic can memorize this table. He must continually refer to the table to get the approximate metric equivalents of English sizes, and not one of the latter has an equivalent in even millimetres.

Our metric friends in their reply to our argument, section IV, p. 667, say: "A large number of the articles enumerated would require no immediate change other than that of name, until such time as they are superseded by new tools of the desired absolute dimensions. Old tools are continually being displaced by new, and now more rapidly than at any previous period."

"No immediate change other than that of name." Then the one hundred and twenty-nine articles or sets of articles used in producing one size, viz., $1\frac{1}{4}$

inch, in the shop of Wm. Sellers & Co., instead of being named "inch-and-a-quarter" would require an immediate change of name to "thirty-one point seventy-five millimetres," or, say, "thirty-two millimetres" for short, until the one hundred and twenty-nine articles "are superseded by new tools of the desired absolute dimensions," say 30 or 32 millimetres, as may be decided upon as being a desirable absolute dimension.

"Old tools are continually being displaced by new." Yes, but they are being displaced by new tools based upon the same old unit of measurement, the English inch.

The above statement of our metric friends means that "the adoption of the metric system will require two things:

1. An immediate change of name of our existing standard sizes, naming them by their approximate dimensions in millimetres.

2. Finally superseding our present standard sizes of tools by new tools of absolute dimensions in millimetres. The first change will simply introduce confusion and error in calling things by wrong names, and the trouble of learning the new names, such as 9.53 millimetres for the old $\frac{3}{8}$ inch.

The second change, if it were possible to accomplish it, means not only the destruction of our present standards, but the abandonment of our present system of interchangeability of parts, and the adoption of a different one. The change could only be made gradually, if at all, and during the transition period, which would last for at least two generations, we would have the "two systems side by side, with the resulting confusion."

If the metric system were adopted in this country the machine shops would be compelled to have two sets of standards, the first to be used in making articles to fit existing articles, or to fill orders in which the dimensions are in the old system; the second to be used in filling orders to absolute metric dimensions. Instead of four reamers, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{7}{16}$ and $\frac{1}{2}$ inch, we would have the nine following: millimetres, 7.94, 8, 9, 9.53, 10, 11, 11.11, 12, 12.70; thus there would be two metric reamers between $\frac{5}{16}$ and $\frac{3}{8}$ inch, two between $\frac{3}{8}$ and $\frac{7}{16}$ inch, and one between $\frac{7}{16}$ and $\frac{1}{2}$ inch.

The machinist now has sixteen sizes of mandrel up to 1 inch; he would require twenty-five additional ones, up to 25 millimetres, if he used both systems. But if twenty-five sizes are too many, how many standard sizes would he use between 0 and 25 millimetres? He might use ten with $2\frac{1}{2}$-millimetre intervals, five with 5-millimetre intervals, or four with $6\frac{1}{4}$-millimetre intervals, but with four sizes three of them would not be in even millimetres, and with ten sizes five of them would not be in even millimetres, so that seven fractional sizes, 2.5, 6.25, 7.5, 12.5, 17.5, 18.75, 22.5 millimetres, would be needed in addition to the even millimetre sizes. In the English system, four sizes to the inch may be used, four more give intervals of $\frac{1}{8}$ inch, and eight more $\frac{1}{16}$ inch, and so on, each larger size being an even multiple of a smaller.

What advantage does the metric system offer the people of the United States to compensate them for the abandonment of its standards, or for the confusion resulting from having two standards side by side?

APPENDIX II.

Note on the Suggested Retention of English Standard Sizes with Metric Names.

It is proposed by some of the advocates of the metric system that in order to avoid the trouble and confusion consequent upon the abandonment of our present machine-shop standard sizes, we retain these sizes and call them by the names of the nearest equivalent dimensions in millimetres.

Such a course has not been pursued even by those shops which have adopted the system either in whole or in part. The injector department of Wm. Sellers & Co., The Waltham Watch Co., Willans & Robinson, and other manufacturers whose use of the metric system has been cited, did not introduce it by retaining old standard sizes and giving them new names, but by the abandonment of the English standards.

How is it possible that the metric system can be introduced into a shop in the way proposed? Here are a few of the difficulties: A standard gear-wheel size is six diametral pitch, meaning six teeth to each inch of diameter. Will any one give it a new name and say six teeth per 25.4 millimetres or twenty-four teeth per 101.6 millimetres?

A 1¼-inch bolt has seven threads to an inch. Shall we call it a 31.75-millimetre bolt and say it has seven threads to each 25.4 millimetres, or shall we call it a 32-millimetre bolt, scant, and say its pitch is 3.63 millimetres nearly?

Here is a comparison of standard sizes of water pipe, as taken from a French and an American reference book. An inspection of it shows that the American list is superior as a commercial standard, for it has fewer sizes and there is a conformity in the difference between sizes, which the French list lacks. Shall we call a 12-inch pipe a 30-mm. pipe, or a 30½-mm. (12 inches = 30.48 millimetres), and shall we figure its discharge by French rules and get the result in cubic metres, or shall we take its discharge in cubic feet from American tables and translate the result into cubic metres? A short sample of the French and American tables is given to show some of the figures that would have to be handled in the metric system:

Standard Nominal Sizes of French and American Water Pipe Compared.

French Sizes.			American Sizes.	French Sizes.			American Sizes.
M.	Diff.	In. approx.	Inches.	M.	Diff.	In. approx.	Inches.
0.05	...	1.97	2	0.24	0.02	9.45	
.06	.01	2.36	2½	.25	.01	9.84	10
.07	.01	2.76	3	.28	.03	11.02	11
.08	.01	3.15		.30	.02	11.81	12
.09	.01	3.54		.32	.02	12.60	13
.10	.01	3.94	4	.35	.03	13.78	14
.11	.01	4.33		.38	.03	14.96	15
.12	.01	4.72	5	.40	.02	15.75	16
.14	.02	5.51		.42	.02	16.54	
.15	.01	5.91	6	.45	.03	17.72	18
.16	.01	6.30		.48	.03	18.90	
.18	.02	7.09	7	.50	.02	19.69	20
.20	.02	7.87	8	.55	.05	21.65	22
.22	.02	8.66	9	.60	.05	23.62	24

Discharge of Water Through Pipes.

(From French Table.)

Diameter of the pipe 0 m .05			
Section " " " 0 m² .0019635			
Mean velocities, metres per second	0.005	0.01	0.02 etc.
Discharge, litres per second	0.0098	0.019	0.039 etc.
Charge per metre in length .... m.	0.0000076	0.0000166 etc.	

Diameter of the pipe 0 m. 50			
Section " " " 0 m². 196.35			
Mean velocities, metres per second	1	1.05	1.10 etc
Discharge, litres per second	180.95	1.90	199.05 etc
Charge per metre of length. .... m.	0.0030	0.0033	0.0036 etc.

(From American Tables.)

Flow for a Uniform Velocity of 100 Feet per Minute.

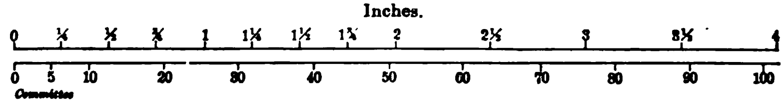
Diameter. Inches.	Area in Square Feet.	Flow in Cubic Feet per Minute.	Flow in Gallons per Minute.	Flow in Gallons per Hour.
2	0.2182	2.182	16.32	.979
20	2.182	218.2	1632.	97.920

Given the diameter of a pipe in inches to find the quantity in gallons it will deliver at a velocity of 100 feet per minute. Square the diameter and multiply by 4.08.

Given the diameter of a pipe or cylinder in inches to find its contents per inch of length in U. S. gallons. Square the diameter and multiply by 0.0034.

Comparison of English and Metric Measures.

Inches.

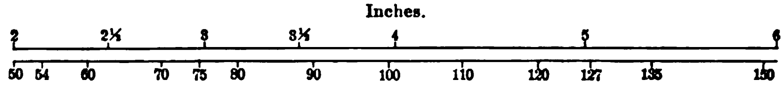


Millimetres.

Fig. 116.

Comparison of English and French Pipe Sizes, Cast Iron.

Inches.



Millimetres.

Fig. 117.

APPENDIX III.

Concerning the Change in Measurement of Type. (See Sec. IV, p. 667.)

The change made by the printers was not from a standard based upon the English inch to one based on another system, but was a change from an unscientific to a scientific measurement and nomenclature based upon the English inch. The point was defined as the 72d part of an inch, instead of being equal to the old French point, which was equal to about $1\frac{1}{12}$ American points, and the several sizes of type were named 6-point, 7-point, 8-point, etc., instead of their former names, nonpareil, minion, brevier, etc. So great is the force of custom, however, that twenty years after the adoption by the type founders of the new system the old names still survive in the trade, and often create some trouble in printing offices.

APPENDIX IV.

Use of the Metric System by Electrical Engineers.

Electrical engineers are said to be largely using the metric system. They are in fact using a mongrel system, comprising the C. G. S., or absolute system, the metric system with the centimetre instead of the millimetre as the unit, English feet, inches and square inches, and several different wire gauges. In a pamphlet on dynamo design recently published are found the following:

Lengths, thickness, etc., 34.9, 20.85, 0.05, 0.706 and 1.16 centimetres.

Speeds, 1,300 and 1,735 centimetres per second, 3,500 feet per minute, 50 feet per second.

Areas, 3,242 square centimetres, 2.2 watts per square inch (=0.341 watts per square centimetre), 600 circular mils per ampere.

Volume, 3,880 cubic centimetres.

Resistance of 1 centimetre of No. 6 B. W. G.

Lines of force, 7,800 per square centimetre.

This is a sample of the confusion that has already resulted from the introduction of the metric system into English literature on electrical engineering. Before a dynamo can be built in any ordinary American machine shop the metric sizes have to be translated, thus: 1,735 centimetres = 56.9 feet; 34.9 centimetres = 13.75 inches; 0.05 centimetres = 0.02 inches; 3,242 square centimetres = 502.5 square inches; 3,880 cubic centimetres = 236.7 cubic inches.

APPENDIX V.

(Extracts from the Report of John Quincy Adams to Congress, 1821.)

"The French metrology, in the ardent and exclusive search for an universal standard from nature, seems to have viewed the subject too much with reference to the nature of things, and not enough to the nature of man. Its authors do not appear to have considered, in all the bearings of the system, the proportions dictated by nature between the physical organization of man, and the *unit* of his weights and measures. The standard taken from the admeasurement of the earth had no reference to the admeasurement and powers of the human body. The metre is a rod of forty inches; and by applying to it exclusively the principle of decimal divisions, no measure corresponding to the ancient *foot* was provided. A unit of that denomination, though of slightly varied differences of length, was in universal use among all civilized nations: and the want of it is founded in the dimensions of the human body." (Page 70.)

"It appears also not to have been considered, that decimal arithmetic, although affording great facilities for the computation of numbers, is not equally well suited for the division of material substances. A glance of the eye is sufficient to divide material substances into successive halves, fourths, eighths and sixteenths. A slight attention will give thirds, sixths and twelfths. But divisions of fifth and tenth parts are among the most difficult that can be performed without the aid of calculation. Among all its conveniences, the decimal system has the great disadvantage of being itself divisible only by the numbers two and five. The duodecimal division, divisible by two, three, four and six, would offer so many advantages over it, that while the French theory was in contemplation, the question was discussed, whether the reformation of weights and measures should not be extended to the system of arithmetic itself, and whether the number twelve should not be substituted for ten, as the term of the periodical return of the unit." (Page 71.)

"The advantages of the English system might, however, be with ease adapted to that of France, but for the exclusive application in the latter of the decimal arithmetic to all its multiples and subdivisions. The decimal numbers, applied to the French weights and measures, form one of its highest theoretic excellencies. It has, however, been proved by the most decisive experience in France, that they are not adequate to the wants of man in society: and, for all the purposes of retail trade, they have been formally abandoned. The convenience of decimal arithmetic is in its nature merely a convenience of calculation: it belongs essentially to the keeping of accounts; but is merely an incident to the transactions of trade." (Page 81.)

"From the verdict of experience, therefore, it is doubtful whether the advantage to be obtained by any attempt to apply decimal arithmetic to weights and measures would ever compensate for the increase of diversity which is the unavoidable consequence of change. Decimal arithmetic is a contrivance of man for computing numbers and not a property of time, space or matter. Nature has no partialities for the number ten; and the attempt to shackle her freedom with them will forever prove abortive.'' (Page 85.)

APPENDIX VI.

From Editorial in the "N. Y. Times," March 3, 1902.

"The unsuccess which has attended the efforts to popularize the metric system in Great Britain and the United States continues to be for its advocates a perennial source of surprise and regret. Its advantages have been explained so often and so fully that nothing remains to be said in favor of it; but the fact remains that it does not interest either the English or the American Nation. They will work to metric scales, gauges, and templets when they have to, but for some reason which it would be difficult to explain satisfactorily to the advocates of the metric system, the Anglo-Saxon mind does not adapt itself to the decimal progression in measurements of dimensions. Those brought up on the units of the inch, the foot and the yard admittedly find them more convenient in mental calculations than the centimetre, decimetre, and metre ever become. The convenient folding of the two-foot rule into halves and quarters of the foot is a natural process of subdivision of the unit which is impossible with one subdivided into tenths. The constantly cited illustration of our coinage as showing that we take naturally to the metric system in subdividing our measure of values, is not convincing. The dollar is a comprehensible unit, but while we divide it into tenths and hundredths in calculation, we much more naturally think of its subdivision into halves and quarters, and but for the intrusion of these coins into what would otherwise be a strictly metric subdivision of the dollar our subsidiary coinage would be very much less convenient and acceptable than we find it. The twenty-cent piece was a failure. Its coinage was a concession to the advocates of the metric system; its withdrawal was necessitated by the fact that all classes of our people preferred the quarter dollar, and the two coins could not circulate together without creating endless confusion."

APPENDIX VII.

Action Taken by the National Association of Manufacturers Through Their Committee on Resolutions, at the Annual Meeting held in Indianapolis, August, 1902.

"It appears to the association, first, that the compulsory adoption of the metric system would probably affect the manufacturing interests of this country as follows: One-third who are exporters to European countries and dependencies would be benefitted; one-third who do business in this country and all other countries would neither be benefitted nor greatly injured; one-third who do business in this country and in England and dependencies, would be seriously injured. For all this the expense and inconvenience would be very great.

"In view of these conditions and of the further fact that the metric system is already legalized for the use of those who find it profitable, this association recommends that no further action be taken on this matter at this time."

COMMENTED ON BY THE EDITORIAL IN THE "NEW YORK TIMES," OF APRIL 25, 1902, AS FOLLOWS:

"This may be briefly supplemented by saying that those who find the metric system convenient in foreign business relations use it now; that those who discover any advantage in using it are perfectly at liberty to do so, and that those who do not want to use it for any and all of the countless good reasons which have been urged against it by representative manufacturers and engineers should not be required to, at incalculable cost and inconvenience. Congress should let this matter alone. If the metric system has the advantages claimed for it, the increasing use of it by the American people will render legislation unnecessary."

FROM THE REPORT OF COMMITTEE ON WEIGHTS AND MEASURES, NATIONAL ASSOCIATION OF MANUFACTURERS, APRIL 9, 1903.

To the National Association of Manufacturers:

In accordance with instructions, your Committee on Weights and Measures has submitted to the members of the Association a series of questions with a view to ascertaining their views regarding the general advisability of the adoption of the metric system by this country, and specifically regarding the desirability of the passage of the bill reported to the last Congress by the House Committee on Coinage, Weights and Measures, and we submit as our report the following summary of the replies:

The total number of replies received was 264. In some cases some of the questions were passed over without reply and in others the answers to some of the questions were too uncertain in tone to permit their being treated as categorical answers. We have in the following summarized the answers to the best of our ability and have endeavored to show by examples how some of the less clear answers have been treated in the classification. No interpretation of these votes would materially change the result.

QUESTION No. 1.—Would the adoption of the metric system tend to increase foreign business in the line you represent?

The answers to this question are as follows:

Yes	60
No	175
Non-committal	12

QUESTION No. 2.—Would the adoption of the metric system be beneficial to domestic business in the line in which you are engaged?

The answers to this question are as follows:

Yes	34
No	206
Non-committal	4

QUESTION No. 3.—Would the adoption of the metric system by our government, for any or all of its departments, including customs houses, arsenals, navy yards and public works, be detrimental to your business?

The answers to this question are as follows:

Yes	98
No	137
Non-committal	2

The answers to this question must of course be viewed in the light of the fact that many manufacturers do no business with the Government, and all such would necessarily answer no.

QUESTION No. 4.—Would it induce the adoption of the metric system by manufacturers and others in private transactions?

The answers to this question are as follows:

Yes	109
No	100
Non-committal	26

QUESTION No. 5.—If our export business should largely increase with countries using the metric system—

(a) Would such increased business lead them to accept our English measurements with less objection than hitherto; or,

(b) Would it lead to the introduction of the metric system by this country under the operation of the natural laws of supply and demand, without further legislation?

The answers to question (*a*) are as follows:

Yes	77
No	81
Non-committal	23

The answers to question (*b*) are as follows:

Yes	105
No	92
Non-committal	25

QUESTION No.6.—Assuming the desirability of an international system of weights and measures, it is of sufficient consequence to justify incurring the following acknowledged disadvantages:

(*a*) The abandonment, or necessity for re-writing, all non-metric engineering literature?

(*b*) Changing our small tools and standard gauges now based upon the standard inch?

(*c*) Abandoning the inch with its binary divisions in common use, such as the half, quarter, eighth, sixteenth, thirty-second, sixty-fourth, and the decimal divisions of the inch?

(*d*) Abandoning the present standard screw threads which are based upon the inch?

The answers to question (*a*) are as follows:

Yes	55
No	153
Non-committal	13

The answers to question (*b*) are as follows:

Yes	47
No	150
Non-committal	12

The answers to question (*c*) are as follows:

Yes	50
No	151
Non-committal	10

The answers to question (*d*) are as follows:

Yes	49
No	152
Non-committal	9

QUESTION No. 7.—Should Congress enact any law to enforce the use of the metric system in any of the departments of the Government?

The answers to this question are as follows:

Yes	51
No	156
Non-committal	6

QUESTION No. 8.—In view of the fact that the metric system was legalized by Act of Congress in 1866, and has therefore been on a legal equality with the English for thirty-six years, to what extent have you made use of it and what has been your practical experience with it?

The answers to this question, while not always in the following words, may be classified as follows:

None	132
Practically none	8
Very little	15
To a limited extent and in a few instances	8
In some departments	2
In one department	2
In laboratory	5
In foreign business (export or import)	27
In special cases or when required	13
In correspondence	3
Some	3
Largely	1
Whenever possible	1
Non-committal	3

The report is signed by,

THEODORE C. SEARCH, *Chairman.*
WILLIAM SELLERS,
ALBA B. JOHNSON,
JAMES M. DODGE.
Committee on Weights and Measures of The National Association of Manufacturers.

APPENDIX VIII.

REPRODUCTION OF A LETTER APPEARING IN THE *Boston Transcript*, DECEMBER 16, 1902, REPLYING TO A DEFENCE OF THE METRIC SYSTEM FROM AN ENGINEER'S STANDPOINT BY PRESIDENT PRITCHETT, OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY:

". . . From a textile standpoint I wish to submit the following facts:

1. In 1900 the textile industry of the United States stood first in the number of employees and third in the value of the finished product, the figures for the three leading industries being:

	Workers.	Value of Product.
Textile	1,029,910	$1,637,484,484
Iron and Steel	733,968	1,793,490,908
Food Products	313,909	2,277,702,010

2. The English yard-pound is now the exclusive standard for all branches of the textile industry in English speaking and other countries,* which include about three-fourths of the world's textile industry.

* India, Russia, China and Japan, which are not English-speaking countries, but which have the weights and measures of their textile industries on the English basis.

3. The English yard-pound is the chief textile standard for so-called metric Europe.

4. With the exception of a local and relatively insignificant Austrian standard, the English yard-pound is the exclusive standard for the linen and the jute industries for the whole world.

5. M. Paul Lamoitier (extracts from his article having been given), a French textile manufacturer and writer, in a recent issue of *l'Industrie Textile*, Paris, the leading textile journal of France, confesses that the attempt carried on for over one hundred years to force the French people to use the metric units in the textile industry has failed. The conclusion cannot be avoided that the proposed attempt to introduce the metric system into this highly organized industry of the United States is doomed to failure, and can only result in the hopeless confusion that accompanies the concurrent use of two or more incommensurable units, such as the yard-pound and the kilogram-metre.

I ask the attention of the textile manufacturers to the following questions:

1. Is a common system of weights and measures for the whole textile world a desirable thing to retain? If not, then the discussion is ended and there can be no objection to plunging into the European chaos of weights and measures. If it is desirable, then the next question to be settled is:

2. Are the benefits of the universal system of textile weights and measures now in its possession sufficient to justify a country (say the United States) in refusing to surrender that system and adopt another, which France has tried in vain for more than one hundred years to adopt, and which is admittedly inferior in many respects to its own?

These are the really serious questions for the textile industry. Any view of the proposed change in our weights and measures taken from the standpoint of any one industry, or profession, no matter how important, is out of perspective in that it makes the whole subordinate to a part. The interests of the masses have been lost sight of in the discussion of the metric question, and yet they, the plain people, would be most affected by any change in our weights and measures.

Twice only in the history of this country has a broad and thorough investigation of the metric system been made for the public benefit. The first time, John Quincy Adams, at the request of Congress, spent four years, from 1817–1821, in this work. The second time (1866–72), a committee of the University Convocation of the State of New York, at the request of Hon. John A. Kasson, chairman of the House Committee on Coinage, Weights and Measures, studied the question for four years.

The decision in both cases was against the introduction of the metric system into the United States.

APPENDIX IX.

The Metric System: A Big Job for a Literary Engineer.

CONDENSED FROM A LETTER IN "ENGINEERING NEWS," FEBRUARY 19, 1903.

There are two serious objections to the adoption of the metric system by the nations using the English units. These objections are: (1) That the millions of people in the United States and England have stored in their memories facts and figures which are based on the inch as the unit of measurement, and they can neither forget them nor mentally translate them into metric units. (2) That every book, newspaper, trade journal, trade catalogue, etc., which they are in the habit of reading or referring to is printed in the English language, and the English system of measurement is part of this language.

During the transition period, which might last fifty to a hundred years, there would be two kinds of measurement literature produced and studied: (1) transition literature, (2) metric literature. The transition literature would have both the English and the metric systems on the same page or on adjacent pages. Thus, under the head of electrical wiring we would have two tables of resistances of different metals, with headings as follows:

French: Specific resistance in microhms-centimetres; resistance of 1 metre weighing 1 gramme; resistance of 100 metres of 1 mm. diameter.

English: Specific resistance, copper = 100; resistance in ohms per mil.-foot.

We would also have tables of resistances, etc., of copper wires, with the following headings:

French: No. of the decimal gauge, diameter in millimetres, section in $mm.^2$, weight in grammes per metre, resistance in ohms per kilometre, length in kilometres per ohm.

English: American wire gauge, Birmingham wire gauge, diameter, inches; area, circular mils.; weight, lbs. per ft.; weight, lbs. per ohm; length, ft. per ohm; length, ft. per lb.; resistance, ohms per lb.; resistance, ohms per ft.

Together with these there would be a set of conversion tables for converting pounds per foot into kilogrammes per metre, ohms per kilometre into ohms per foot, etc.

Then we would have two different steam tables, five lines of each of which would appear as follows:

a.	b.	c.	d.	e.	f.	g.
1.0	99.09	99.58	636.72	537.15	1.701	0.587
1.1	101.76	102.28	637.54	535.26	1.555	0.643
1.2	104.24	104.79	638.29	533.50	1.433	0.697
1.3	106.55	107.14	639.00	531.86	1.329	0.752
1.4	108.72	109.34	639.66	530.33	1.239	0.806

a. Pressure (absolute) kg. per sq. cm.
b. Temperature, °C.
c. Heat of the liquid.
d. Total heat.
e. Heat of vaporization.
f. Volume, cu. m. per kg.
g. Specific weight, kg. per cu. m.

h.	i.	j.	k.	l.	m.	n.	o.
0	14	212.	180.9	1,146.6	965.7	26.36	.03794
0.304	15	213.0	181.9	1,146.9	965.0	25.87	.03868
1.3	16	216.3	185.3	1,147.9	962.7	24.33	.04110
2.3	17	219.4	188.4	1,148.9	960.5	22.98	.04352
3.3	18	222.4	191.4	1,149.8	958.3	21.78	.04592

h. Gage pressure, lbs. per sq. inch.
i. Abs. pressure, lbs. per sq. inch.
j. Temperature, °F.
k. Total heat above 32° in the water.
l. Total heat above 32° in the steam.
m. Latent heat in the steam.
n. Volume, cu. ft. per lb.
o. Weight, lbs. per cu. ft.

Under the steam tables it would be explained that pressures of steam in metric countries are commonly expressed in atmospheres, but that modern writers express them in kilogrammes per centimetre, and that 1 kilogramme per square centimetre is nearly but not quite, an atmosphere. A conversion table would be given in style something like the following:

> 1 atmosphere = 14.697 lbs. per sq. in. = 29.992 ins. (760 mm.) of mercury = 1.033296 kg. per sq. cm. 1 metric atmosphere = 1 kg. per sq. cm. = 0.96777 atmosphere = 735.51 mm. (29.025 ins.) of mercury.

The metric literature would be much simpler, thus:

> 1 atmosphere = 760 mm. of mercury = 1.033296 metric atmosphere = 1.033296 kg. per sq. cm. 1 metric atmosphere = 1 kg. per sq. cm. = 0.96777 atmosphere.

This little conversion table is necessary because there are two atmospheres used in the French system, one the actual mean pressure at the sea level, or 1.033296 kilogrammes per square centimetre, and the other an ideal atmosphere, in which there is "the beautiful correlation between measures of length and of weight," viz., exactly 1 kilogramme per square centimetre.

It would not be much of a job to produce the metric literature, for it would be necessary only to reproduce the rules, tables, formulæ and data now printed in the metric countries. There would be no tables of structural shapes, for instance, ranging by even inches from 3 to 24, with their corresponding weights per foot, and coefficients of strength in pounds, but there would be other tables in which there would be structural shapes from 80 millimetres up to, say, 600 millimeters, advancing by intervals of from 20 to 50 millimeters, with their corresponding weights in kilograms per metre, and with coefficients corresponding to metric measures of length and weight.

The big job, however, would be to produce the literature of the transition period. It would include, in the tables of beams, for instance, all the existing standard sizes, in even inches of depth, with their corresponding metric equivalents to the nearest tenth of a millimetre, together with the dimensions, both English and French, of length, breadth of flange, and thickness of web, the weight per yard and per metre, in pounds and kilogrammes, and the coefficients for computing strength in both systems. Besides this there would have to be new tables of the new sizes, 20 to 600 millimetres in metric measures and in their English equivalents.

During the transition period the mechanical articles in the "Encyclopædia Britannica" and all other cyclopædias and other works of general reference would have to be reprinted in the transition language, otherwise they would not be readable by the people of the period. When the reform (?) was at last accomplished they would have to be reprinted again, making them altogether metric, and then the old books would all find their way to the paper mill.

The engineer's pocket-books would also have to be reprinted in the transition language, and then many years later completely metricised. Every present owner of one of these pocket-books, if the metric system is coming very soon, would have to provide himself with both of the new books, and the transition book would be at least half as large again as the present book, and of course would sell at a higher price. The first editions also would have so many typographical errors and errors of computation that the new editions would sell rapidly.

To get an idea of the size of the job that will have to be done if the impending reform is accomplished, let us consider some of the tables, etc., that are found in these books based on the English inch. They are:

Wire and sheet-metal gauges.

Weight and specific gravity of substances.

Weights of standard sizes of bars, rods, tubes, structural shapes, pipes, fittings.

Thickness of pipe for different pressures.

Standard pipe flanges, boiler tubes, riveted pipe, brass, copper and lead pipe.

Standard sizes of screw threads, taps, set screws, machine screws, nuts, bolts, rivets, washers, nails and spikes, wire, wire rope, cables, chain, fire-brick.

Strength of materials, rules, tables, formulæ, etc.: safe loads on columns, beams, shafts, bolts, bursting pressure of pipes, cylinders, boilers; results of tests of materials, bars, chains, springs, riveted joints, timber, alloys, ropes, wire ropes.

Specifications of all materials.

Velocity of falling bodies, height due to velocity.

Air, properties of, compressed air, tables and formulæ, flow of air in pipes, air compressors, fans, blowers.

Heating and ventilating, formulæ and tables.

Water, weight, pressure, flow, pumps and pumping engines, turbines.

Steam, properties of, steam pipes, boilers, chimneys, heaters, engines, condensers, flywheels, governors.

Transmission machinery, gear wheels, shafts, pulleys, belts, rope, wire rope.

Foundry and machine shop practice.

Refrigerating machinery.

Locomotives, cars, railroad work.

Marine engines, ships, etc.

Electrical Engineering.

The list might be extended indefinitely.

Another branch of technical literature that would have to be reprinted is that issued by the several correspondence schools. The hundreds of thousands of students of these schools would all have to be furnished with instruction papers in the transition language. The instructors in the schools also would have a big job added to their present one in correcting the additional errors made by their pupils on account of their want of familiarity with the new units of measurement.

It may be said that the transition literature would not be needed, that a good book of conversion tables would fill all wants in transposing from one system to the other. But as long as manufactured articles, such as bars, tubes, etc., are made in standard sizes by the English system, so long would we require tables of weight, capacity, etc., of these sizes, and such tables can not be converted from one system to the other without great labor and liability to error. The use of printed tables giving the weights, capacities, etc., in the French system, together with the sizes in English measures, would be needed. Just such tables are already found in catalogues of American manufactures, printed in French and German. There is a table of this kind in a French book of "Notes and Formulæ," 1897 edition, giving weights in kilograms of cast-iron pipe, the sizes of which are given as follows:

Inches	1½	2	2½	3	3½	4	5	6	7	8
Millimetres	41	54	67	81	94	108	135	162	189	216

On another page there is another table of weights of other sizes of pipe, viz.:

Millimetres, 40, 50, 54, 60, 70, 75, 80, 90, etc.

The first table represents the sizes of pipe that would be made during the transition period; the second the sizes that would be made when the metric system had been completely introduced.

The same book gives a table of screw-threads "Systeme Whitworth," with the following figures:

Diameter, inches	¼	5/16	⅜	7/16	½	⅝	¾	⅞	1
Diameter, millimetres	6.35	7.94	9.52	11.11	12.70	15.87	19.05	22.22	25.40
Threads per inch	20	18	16	14	12	11	10	9	8
Pitch, millimetre	1.27	1.41	1.59	1.81	2.11	2.31	2.54	2.82	3.18
Diameter, core, mm.	4.72	6.09	7.36	8.64	9.91	12.92	15.74	18.54	21.33

The book says of the Whitworth system, that it has been adopted for a long time in England and in Germany: "It is very desirable that we reach some universal rules for the pitch of screws, but the widely extended use of the Whitworth sizes prevents it, until England has adopted in practice the metric system."

So it appears that even in France, after more than a century of the metric system, the transition period of mechanical literature is not yet at an end.

The conclusion from the above study of the literary question is that the work to be done in converting the English-speaking race from the English to the metric system is so appalling in its magnitude that it can never be done at all. There will be no transition period and no transition literature. There may be laws passed making it "the" legal system, and the departments of the government may be compelled by Congress to use it in all business transactions, but the people as a whole are no more likely to adopt it than they are to give up the English language and adopt French in its place.

APPENDIX X.

The Use of the Metric System in Recent English Technical Literature.

The troubles which will ensue during the transition period which would follow the attempt to introduce the metric system into technical literature are already foreshadowed by the increasing tendency of some writers to make a partial use of the metric system in their books. The following comments on this subject are made in a review, in *Engineering News* of March 19, 1903, of Campbell's "Manufacture and Properties of Iron and Steel."

We regret to see that the author mixes up the English and metric systems of weights and measures in this chapter. In one table he gives in the headings of columns, pounds of coke per ton of 2,240 pounds of iron, kilograms of carbon per ton of iron, cubic metres of gases per ton of iron and heat value of gases per ton of 2,240 pounds iron in French calories. In a foot-note he refers to an error made by Sir Lowthian Bell in giving calories per ton inseatd of calories per 20 kilograms, which arose from his adopting a new unit of 20 kilograms as his base of calculation. Mr. Campbell may not have made any similar error himself, but his use of tons, pounds, kilogrammes, cubic feet and cubic metres indiscriminately makes hard reading, and is a fine sample of what we shall have to submit to for many years to come until the metric advocates cease their attempts to destroy the English system of measurement and to introduce confusion in our language. We suggest also that it would have been simpler to make all calorific computations of blast-furnace problems in weights instead of part weight and part volume. The volume calculations, cubic feet and cubic metres, always refer to volumes at some standard temperature (32°, 39°, or 62 F.) and not to the actual volumes, while weights are independent of temperature. Only one unit, the pound, need then be used in all calorific computations.

Chapter IX. is on the combustion of fuel. Here the author again uses the metric system, with its kilogrammes, cubic metres and calories, where pounds, cubic feet and British thermal units would have been just as good, and more acceptable to the English reader.

A sample paragraph from Mr. Campbell's book is the following:

Bell gives the weight of air blast as 103.74 kilogrammes per 20 kilogrammes of iron = 5.187 kilogrammes to 1 kilogramme of iron = 5270 kilogrammes per 2,240 pounds iron, which for a furnace making 300 tons in 24 hours is at the rate of 1098 kilogrammes = 849 cubic meters = 29,983 cubic feet per minute.

If English measurements alone were used this would read:

According to Bell the weight of air blast is 5,187 pounds per pound of iron = 11,619 pounds per ton of 2,240 pounds. For a furnace making 300 tons in twenty-four hours this is equivalent to 29,983 cubic feet (at 32° F.) per minute.

Why do some English writers use the metric system (to a partial extent) in their books?

1. Is it to save themselves the trouble of translating the figures from the metric into the English system? As all technical books are, or ought to be, designed to convey informations to the reader in the clearest manner possible, involving him in the least mental fatigue, the author owes it to the reader to take the trouble to translate metric dimensions into English, just as he would translate a foreign verbal expression into English.

2. Is it to make their books more readable by foreigners? Any foreigner who does not understand the principal English dimensions, feet, inches and pounds, is not likely to be able to read an English book at all. As the English readers of an English book are likely to be a hundred times as many as the foreign readers, why should the latter be considered, to the inconvenience of the former?

3. Is it because they favor the propaganda of the metric system and wish to be known as among those who desire to force it on the English-speaking world? Then they must be numbered with the spelling reformers and other faddists, and let alone, for no argument will reach them.

APPENDIX XI.

Advantage of Fractions over Decimals in Computation.

In the English system of weights and measures the computer may use either common fractions or decimal subdivisions as he chooses, and often he will find the fractions the easier. The following actual problem recently came up in the writer's practice:

A conveying belt 100 feet long, running 400 feet per minute, delivers 20, 40, 60, 80 or 100 tons of 2,000 pounds per hour. What is the load on the belt for each rate of delivery?

SOLUTION BY FRACTIONS.

Tons per hour = T........ ...	20	40	60	80	100
Tons per minute = $\frac{1}{60}$ T.......	$\frac{1}{3}$	$\frac{2}{3}$	1	$1\frac{1}{3}$	$1\frac{2}{3}$
Load on belt = $\frac{1}{4}$ of $\frac{1}{60}$ T......	$\frac{1}{12}$	$\frac{1}{6}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{5}{12}$
Load on belt in pounds........	$166\frac{2}{3}$	$333\frac{1}{3}$	500	$666\frac{2}{3}$	$833\frac{1}{3}$

SOLUTION BY DECIMALS.

Tons per hour = T...........	20	40	60	80	100
Tons per minute = $\frac{1}{60}$ T	0.3333	0.6667	1	1.3333	1.6667
Load on belt = $\frac{1}{4}$ of $\frac{1}{60}$ T......	0.0833	0.1667	0.25	0.3333	0.4167
Load on belt in pounds........	166.7	333.3	500	666.7	833.3

APPENDIX XII.

Action of the Cincinnati Manufacturers on the Metric System.

(From the *American Machinist*, Nov. 27, 1902.)

The Franklin Institute Committee on the Metric System has, as many of our readers are aware, circulated a list of questions among the manufacturers of the country. The manufacturers of Cincinnati have taken concerted action in replying to these questions, and as their answers give the views of a large and important manufacturnig section, we consider it only proper that they be given in our columns. The questions and answers are sandwiched together below:

1. Is it not desirable to simplify and change the system of weights and measures at present in general use in this country?

A.—It is desirable to simplify the present system if it can be done without introducing more confusion than is saved, which we doubt. It is not desirable to change the system.

2. In view of the fact that the following countries officially and customarily employ the metric system of weights and measures—namely, France, Germany,

Austro-Hungary, Norway and Sweden, Grand Duchy of Finland, Holland, Belgium, Switzerland, Spain, Portugal, Italy, Servia, Roumania, Bulgaria, Greece, the Ottoman Empire, Japan, China (thirty-eight ports), Egypt, Mexico, the Central American and South American countries, the dependencies of the above-mentioned countries and the Latin acquisitions of the United States—do you not consider that it would be advisable to adopt the metric system in the United States with the view of bringing about international uniformity in weights and measures?

A.—The statement that the countries named "customarily employ the metris system" is a pure assumption. No evidence of this is submitted, while on the contrary, all available evidence shows that in some of these countries the system is used but little, and in none of them is it universal. Even in France the old units are still in wide use. Considering the age of the system, this is sufficient proof that it cannot become universal, and all arguments based on the assumption that it can be fall to the ground.

3. Would not the introduction of the metric system benefit the foreign trade of the United States?

A.—Of the millions of dollars of machine tools which the members of the Association have sold to France and Germany, the great majority have been sold without request or suggestion that any of the dimensions be made in accordance with the metric system. The only changes that have been asked for have been in occasional measuring and adjusting screws. In view of this experience and of the unexampled growth of the export trade of this country during the past half-dozen years we cannot see any need of changing for the benefit of foreign trade.

4. Do you not consider that the introduction of the metric system would facilitate and abbreviate the computations which present themselves in the ordinary occupations of life?

A.—Theoretically yes, though to an extent that has been grossly exaggerated. The supposed gain, considered in its economic value to the nation, we consider to be trifling. Moreover, this trifling gain is dependent upon the old units becoming extinct, which in France and Germany they have not done. On the other hand, the existence of both old and new units in those countries serves in many instances to *increase* the labor of calculations and to nullify the whole argument based on the theory of the metric system.

5. Would not the introduction of the metric system, by practically limiting the units of weights and measures to (1) the metre, (2) the gram, (3) the litre and (4) the are; and in view of the simple prefix system of decimal multiples and submultiples existing in that system, assist in measuring and expressing quantitative values of all kinds?

A.—Should the old units become extinct, yes; but the experience of metric-using countries shows that they will not. The adoption of the system will thus *add* to the number of units to be learned.

6. It has been found upon investigation by the Bureau of Education of the United States and the Select Committee on Weights and Measures of the House of Commons of Great Britain that a year of the school life of children could be saved through replacing the customary weights and measures by the metric system. In view of this fact [?], is not the change to be desired from an educational standpoint?

A.—This conclusion is also based on the theory that the old units will become extinct. If the old units are to continue, as all experience shows they will, the conclusion is nullified and reversed—the children will have an additional system to learn and their labors will be *increased*, not diminished.

7. What length of time do you think would be required to instruct artisans in the use of the metric system?

A.—The experience of France has shown that the change cannot be completed in a century. In view of this, we regard what anyone "thinks" about the matter as of no importance.

8. Would the fact that in the decimal system continued fractional subdivision by 2 cannot be conveniently carried so far as in the customary weights and measures with common fractions seriously militate against the introduction or use of the metric system?

A.—We consider the advantage of the binary system of division to be too important to be dispensed with.

9. If the metric system were adopted within a few years in your business, would its gradual adoption entail great expense? How could this expense be minimized or avoided?

A.—To adopt the system gradually would involve making machines for years with part English and part metric dimensions, with constant change as the English dimensions are dropped—that is, until the transition is complete. During this period there could be no standardized production, but constant change. We cannot regard the use of both systems on the same machine as a thing to be tolerated, much less deliberately encouraged. To continue existing units on old machines while adopting the metric units on new ones helps matters but little, as in all lines of machines many parts are common to different sizes. Moreover, the whole question is based on the idea that the sacrifice of the change is measured by the cost of buying new small tools. On the contrary, the chief sacrifice is in the changing of standardized things—in the throwing away of standards, the value of which we will not know until we lose them. The value of shafting and pulley standards, for example, lies in the fact that by reason of them shafting and pulleys may be made in large quantities and therefore cheaply; that because their fitting is insured, they can be made in advance and sold from stock as needed, instead of being made to order at increased cost and delay; that pulleys can be changed about as needed, and if thrown out of use become again available for any shaft of their size, whenever wanted. Who would think of estimating the value of shafting standards to the country, by the value of the turning and boring tools and gauges in pulley and shafting factories? Nevertheless, that is exactly what you do when you tacitly assume that the cost of changing our shop standards is measured by the expense of new tools. Imagine, if you can, the confusion that would prevail if pulleys and shafting had never been standardized, and you will begin to understand how ridiculous is your assumption that the cost of this change can be measured by the cost of small tools. Into the loss due to the destruction of standards the element of time does not enter, and we therefore regard the idea of a gradual change as simply postponing and refusing to face the difficulties of the problem.

10. Are you in favor of the bill, H. R., 123, as reported from the Committee on Coinage, Weights and Measures, and which it is expected will be considered at the coming session of Congress, and which reads as follows? "A bill to adopt the weights and measures of the metric system as the standard weights and measures in the United States. (1) Be it enacted by the Senate and House

of Representatives of the United States of America, in Congress assembled, (2) that on and after the first day of January, 1904, all the departments of the government of the United States, in the transaction of all business requiring the use of weights and measurement, except in completing survey of lands, shall employ and use only the weights and measures of the metric system; and on and after the first day of January, 1907, the weights and measures of the metric system shall be the legal standard weights and measures of and in the United States."

A.—No. We believe that the difficulties of the change have been ridiculously underestimated, and that the metric system offers no compensating advantages. We regard the whole matter as a shop affair exclusively, since the confusion and expense must be borne by the shops. We therefore regard the intrusion of those who have no pecuniary interest in shops, as unwarranted.

These answers were signed by the following firms of the Cincinnati district: American Fire Engine Company, Belmer Machine Tool Company, Cincinnati Machine Tool Company, Cincinnati Milling Machine Company, Cincinnati Planer Company, Cincinnati Shaper Company, Dreses Machine Tool Company, J. H. Day Company, William E. Gang Company, Greaves, Klusman & Co., Laidlaw-Dunn-Gordon Company, Lane & Bodley Company, J. M. Robinson & Co., Sebastian Lathe Company, Schumacher & Boye, John Steptoe & Co., Smith & Mills, Triumph Electric & Ice Machine Company, Cincinnati Punch and Shear Company, Bradford Machine Tool Company, American Tool Works Company, Jos. S. Blettner & Co., Barker & Chard Machine Tool Company, Dietz Machine Tool Company, Fosdick & Holloway Machine Tool Company, I. & E. Greenwald Drill and Tool Company, R. K. Greenwald & Co., Bickford Drill and Tool Company, R. K. LeBlond Machine Tool Company, Springfield Machine Tool Company, and others whose names we have not been able to get.

PRO-METRIC REPLY TO APPENDIX XII.

The answers to these questions, which answers were made by concerted action of the manufacturers named, are based almost, if not entirely, upon the paper of F. A. Halsey, which had been previously read at the Cleveland meeting of the Machine Tool Manufacturers' Association. This paper was essentially the same as that presented before the American Society of Mechanical Engineers and which accompanies this report. At the Cleveland meeting referred to there was no one to say a word on the other side, and the fact is that a very large majority of those who signed the answers as given did so without having given the matter any serious study or consideration. In fact, most of the signers have, we believe, never given any serious attention to the question of the relative merits of the two systems. They are busy men, and while their opinions would be valuable upon this or any other matter connected with the art of machine construction where they had taken time and pains to examine it on both sides and with care, we feel certain that, owing to the peculiar manner in which this action was brought about, it should have no more weight than Mr. Halsey's paper itself, which is entirely one-sided and does not profess to be an impartial examination of the question.

Some of those who signed the answers have said since signing them that they have seen new light upon the subject, and we think many of them would answer differently if it were to be done over again.

On the same page of the *American Machinist* referred to is a letter which was written by an engineer connected with a machinery house in Paris, which house has sold many thousands of dollars worth of American machine-tools in France and elsewhere in Europe, chiefly through the efforts of the writer of the letter—a man who is friendly to American machinery interests and of undoubted sincerity. We commend this letter to careful attention; it is as follows:

Editor American Machinist:

"I have carefully followed the valuable articles appearing in your paper in regard to the bill that the United States Government proposes for the adoption of the metric system in your country. I think that I have some experience with the sale of American tools in Europe, and believe that American tool manufacturers are quite wrong in systematically resisting the proposed bill as far as their European trade is concerned. Their German competitors will probably make a demonstration of this opinion.

The second resolution of the Cleveland convention of the National Machine Tool Builders' Association reproduced at page 1525 of your paper is somewhat puerile. The machines referred to were accepted by customers with only the adjusting and measuring screws made metric, because at that time, namely, two or three years ago, the demand was very active and the buyer accepted what the manufacturer was willing to give him; but conditions have changed a great deal in Europe and a large number of tool users now buy German tools, while they used to buy American tools simply because the former are manufactured thoroughly to the metric system.

There is no doubt that the metric system will be exclusively used the world over some day, even in the United States, and it would seem to me that since the American tool manufacturers will have to make the change from the English system to the metric, it would not cost them any more now than later, and of course the sooner will be the better for them, as when their European trade is lost and in the hands of their German competitors it is doubtful that it will be easy to secure it again.

APPENDIX XIII.

If the Change to the Metric System were Desirable the Difficulty of Making it is Enormous.

Our metric friends say they are opposed to compulsory legislation in favor of the metric system—yet how can it ever be adopted in this country without it. Even thirty years of compulsory legislation has failed to wipe out the old measures in Germany. German cost calculations of a piece of worsted goods—as explained in a German textile treatise—are thus described in the *Textile World:*

"The raw material is purchased by the *English pound.* The finished goods are sold by the *French metre.* The yarn counts are *English*, while the length and width of the finished goods are *metric.* The length of the yarn is expressed in *metres*, while the counts are *English*, based upon the *yard* and the *pound.* From this hodge podge the weight of the yarn is calculated in *grams*, which is extended by another arithmetical somersault at a price given in marks per *English pound*, and to cap the climax the total length of the yarn in *metres* is reduced to *English yards* and then to *English skeins* of 560 yards each."

Mr. Halsey says: "In the mechanical industries of Germany we have the testimony of an American engineer who has for three years occupied a leading position in a German machine tool works that 'In Germany alone there are not less than half a dozen (inches of different values) of which two, the Rhenish and the English, are in such very general use as to cause great confusion. * * * Nearly universally the carpenters and other building mechanics use the Rhenish inch,' and we have other testimony showing that ship, boiler and pipe work are done on the inch basis, while the practically universal use of English pitch screw threads in Germany is known to all who are well informed.

"Even in France the old units persist after more than one hundred years of the metric system:

"In trade reports in French newspapers, the pipe of 105 gallons will be found as the unit of stock on hand and of sales of spirits, while the piece of varying capacity, the tonneau, the piece, the feuillette and the mesure are units of wine measure. Sugar and coffee are sold by the sac, firewood by the cord, potatoes by the setier, apples, etc., by the minot, lumber by the dozens of solives, madriers and planches, while land is advertized and sold by the perche, arpent and journee.

"In Spain, which has been nominally metric for forty years, an American correspondent and manufacturer living at Barcelona tells me that 'not more than half the everyday business transactions are carried out on a metric basis.' Linear and superficial measures include the palmo, the vara, the cana and the destre Oils and wines sell by the cuarto, arroba and cantara; cereals by the fanesa and ferrado; coal and coke by the arroba, quintal and tonelada, while there are about twenty different libras or pounds in use, the value of this unit, like many of the others, varying with every province.

"And in Mexico, nominally metric for eighteen years, the facts are that in the work pertaining to locomotives, cars and shop tools, the practice of nearly all railroads in Mexico is based on the inch exclusively. Lumber is sold by the English system, while dealers sell so many metres of such and such inch pipe or wire rope and so many kilograms of ½, ¼ or ⅛ inch bar iron—the last of Mexican manufacture—and, added to these examples of simplicity and uniformity, the old Spanish vara, carga and arroba are in frequent use."

APPENDIX XIV.

Concerning the Extent of the Adoption of the Metric System.

(From an editorial in *The Engineer*, Cleveland, O., January 15, 1903.)

"The extent of the practical employment of existing systems: The sum total of advantages that might result from inaugurating any different system at the present time cannot be estimated by considering merely the number of governments which may not only have adopted it, but rendered its use compulsory, or the number of countries in which the system may be nominally operative. The greater inconvenience and expense must necessarily be borne by the countries making the larger use of the system which it is intended to supplant.

"Whatever system may be agreed upon for universal adoption, the nations engaged in manufacture will be the larger users of the system. The number of countries employing the metric system furnishes no indication whatever of the loss in time, stocks and money, that would be incurred were those employing the

English system obliged for any reason to change to another. From a study of available statistics it is very probable that the number of persons in the United States, England, Germany, and possibly France, who have adopted the English system is greater than the number of persons using the metric system in all countries combined. If this be so, assuming that a universal system should be adopted, a change from the French to the English system will be much cheaper than a change from the English to the French, wherever the two systems are used.

"While the number of countries in which the metric system has been adopted is much larger than the number employing the English system, the total of firms and individuals constantly using the metric system, and the value of the property concerned, shrink to small proportions when compared with the number of people engaged in industries using the English system and the assets they represent."

APPENDIX XV.

Some Opinions of Engineers who are Familiar with the Metric System.

FROM "ENGINEERING NEWS," FEBRUARY, 1903.

C. W. Baldrige, Winona, Minn. "The fact that all city subdivisions, land subdivisions, and practically all measurements of anything, for record or of permanence, in the United States, are made in the system of which the foot is the unit, should constitute an insurmountable obstacle to the changing of that unit.

"A few months' work among the old vara measured 'Spanish grants' of Southern Texas was sufficient to convince me of the undesirability of changing a unit of measurement; but I do think it would be desirable to build up a decimal system, so far as it is possible, upon our present most common units as a basis."

A. S. Robinson, St. Ignace, Mich., who has had a great deal of experience with the metric system, referring to railroad surveying in Mexico, says: "We find that the 20 millimetre station already makes 50 per cent. more work over the American system on the level notes and profile, correspondingly increases the liability to error, introduces still another liability to error in figuring grades, and presents no improvement over the American system.

"On construction with 10 millimetre stations the cross-section would then have to be taken at every 10 millimetre and lose the benefit of the factor 20 in the calculation of earthwork, or at the 20 millimetre station, thereby acdnowledging the metric to be 'a makeshift of a decimal system.' The latter is the case.

"In running curves by deflection angles, fractional stations fall more frequently on even feet than on even metres, and therefore the engineer has more 'trouble with those annoying and distracting decimals of a degree' in the metric than in the foot system."

E. Sherman Gould, Yonkers, N. Y.: "Let me premise by saying that I belong to the class which perhaps has the best right to form and express an opinion on the subject, having used both the English and metric systems in a somewhat extended engineering practice at home and abroad, beginning with my education in a French engineering school.

"If we were to adopt the metric system, even admitting for the argument that it is better than ours, we would not find our work of measuring, recording and calculating materially lessened. Long calculations would be as troublesome and as liable to error as ever, and probably the majority of people, not specialists in any particular art, would be unable to say which they preferred, after a fair trial.

"I believe the radical defect of the metric system, pure and simple, is that it proceeds on the assumption that it is possible to have one unvarying standard of weighing and measuring for all uses, small and great. You might as well, hyperbolically speaking, ask the blacksmith to use the same tools as the carpenter, and a single tool at that. I grant that if we must have the same yardstick to measure the interstellar spaces and the eye of a needle, the metric system is as good as any I happen to know of, but why should we so limit ourselves? I think it is characteristic of the grand industrial race that uses English measures, that each trade uses the unit and subdivision best suited to its purpose, with perfect indifference as to whether or no any one else likes it. The reproach made against our system on the grounds of its complexity seems to me to be its greatest merit from the practical point of view."

FROM "PROCEEDINGS" OF THE ENGINEERS' SOCIETY OF WESTERN NEW YORK, DECEMBER, 1902.

Paper by Mr. Chas. H. Tutton, Vice-president. "The most difficult part of mathematics for students to grasp is decimals, and wherever possible they are avoided by business men, and educated gentlemen though you are, it would be perfectly safe to assert that there is not one of you who could not easily be made to stumble over this mode of calculation.

"Looking over the metric system, you will, perhaps, be surprised to find that it is not so simply decimal after all.

"The unit of length is the metre, (39.37 inches by law).

"The unit of solid measure is the stere, and is one cubic metre (35.317 cu. ft.)

"The unit of square measure is the are, but it is not one, but 10 metres square (1076.4 square feet.)

"The unit of weight is the gramme (.0022 pounds avoirdupois) but it is not one cubic metre, but one cubic centimetre, and the decagram, or ten grammes is not one cubic decimetre although it is ten cubic centimetres, the cubic decimetre being equal to 1,000 grammes or one kilogramme.

"The unit of dry and fluid measure is the litre (.0353 cubic feet), but it is neither one cubic metre like the unit of solid measure, nor ten cubic metres like the unit of square measure, nor one cubic centimetre like the unit of weight, but is one cubic decimetre.

"In fact, the bases of the different weights and measures are as variable as our own, and the claimed facility for theoretical transformations will vanish like the dew of the morning when brought before the light of day.

"The writer has transformed a great many formulae from one system of measures to another and knows whereof he speaks."

Mr. S. M. Kielland. (Discussion): "We know that Germany is a very disciplinary country, that is, they introduce a measure and carry it through by government order—soldiers. Still, within the last month, there has been introduced a motion in the German Reichstag to legalize the use of the half-pound and quarter-pound as part of the national system of weights, it having been found impossible to familiarize the common people with the use of that kind of unit unless divided into halves and quarters.

"I was born in a country where a binary system similar to that of America to-day—pounds and feet—was changed to the metric system. . . . It was a "craze" when some years ago, nations looked to France for pretty nearly everything in scientific lines. . . . Without taking time to look into or study the matter, the metric system was adopted by all of the leading nations of Europe, with the exception of the Anglo-Saxon nations and Russia. When I went over to Norway, Sweden and Denmark, a few years ago, after having been away about twenty-five years, I found the common or old measures as well as the metric measures in use by the common people, especially amongst the traders and peasantry. The most of their trade and dealing is done by the old system the same as they used to do before the metric system was adopted. Of course, if we want these difficulties and complications by the use of two or more systems which Mr. Tutton has so well pointed out, we can have them by making use of the metric system compulsory in the United States.

"America, is, to-day, a mighty nation. We are taking our share,—pretty near the governing share, you might say,—from one-half to one-third, of the business of the world, and why should we change our system now? Let them change theirs to ours."

Col. Francis G. Ward. (Discussion): "I was brought up under the metric system, and so might differ somewhat from the gentlemen as to the application of it. I resided for eight years in a country where the people were familiar with its use., I doubt whether it is advisable to adopt it in the United States.

"Naturally, when you begin to compare it and translate from one system into another, you meet the same difficulties as translating from one language into another. You lose the value of any work when you translate it. You should be able to read the work in its original. The system that we have in this country is the old English system. *Good enough for us.*"

The following resolution was offered, duly seconded and *unanimously* adopted:

"RESOLVED, that the secretary of the Society notify our members of Congress that in the opinion of the members of the Engineers' Society of Western New York, the passage of any bill making the "Metric System" compulsory in this country is premature, and such action should not be taken without full and free discussion throughout the country."

FROM A LETTER BY WILLIAM SELLERS, FEBRUARY, 1903.

"I think it would be deplorable if this Society should lend itself to the further introduction of this system in this country. The cost would be enormous, and we should in the matter of screw threads and standard gauges, which are now established in this country, at once place ourselves in the position of the mechanical engineers of Europe, who have, after all the years of forced legislation, a mixed system, compared to which Mr. Southard's statement concerning the different pounds, quarts, yards and tons in our system becomes significant.

"Mr. Southard says, 'All agree that a universal system is most desirable, and all agree that our system never can become universal.' I suppose it would be as universally conceded that a uniform language would also be desirable, but there are some desirable things that cost too much for the advantages to be gained therefrom."

APPENDIX XVI.

REPORT OF THE COMMITTEE ON WEIGHTS, MEASURES AND COINAGE. PRESENTED TO THE NATIONAL ACADEMY OF SCIENCES, APRIL 17, 1902.

The Committee on Measures, Weights and Coinage, to which was referred the letter of the Honorable J. H. Southard, Chairman of the Committee of the House of Representatives on Coinage, Weights and Measures, respectfully report as follows:

The letter of Mr. Southard requests the opinion of the academy upon two points. The first of these is whether the International Metric System is desirable for general use in this country.

Your committee is of opinion that this is not strictly a scientific question. Undoubtedly for scientific purposes the metric system is preferred. Certain unquestionable conveniences, not of the highest urgency, would attend its general use for most purposes. But the most important uses of any system of weights and measures are those of machinery, of the railway system, of mechanics generally. Here we have to distinguish between a nominal and a real use of the metric system. If by the sole use of the standards of the metric system be meant that measures are to be expressed, so that when an inch is meant, 25.4 millimetres be said and when a quarter of an inch be meant, it be called 6.35 millimetres, the effect would be considerable inconvenience and nothing more. If the United States Bureau of Weights and Measures ceased to use any other standards than the metric ones after next year, the result would be to lesson the utility of that bureau, the work of which in this department would at once be done by private parties. It does not seem probable that even the most ardent adherents of the metric system would voluntarily call an inch 25.4 millimetres, since they are perfectly free to do so now. It is certain that neither the practice by government bureaus of calling an inch 25.4 millimetres nor the cessation of the comparison of English standards by the government would have any effect whatever upon the machinery and railway systems of the country, to the well-being of which the continuance of the real employment of the inch is vitally necessary.

But if the government of the United States proposes to enter upon a warfare against the real use of the inch in machinery and the railway system, we must say that the certain cost to the people will be that of no small war, and the issue will be as uncertain as that of any war. The mechanical pre-eminence of the United States would be the price that would be paid for success in this struggle. The advantages of it would be insensible to ordinary men.

In view of these considerations your committee is constrained to advise that the abandonment of the inch is distinctly undesirable, whether an abandonment in words or in fact be contemplated.

Holding these views upon the first question submitted, and consequently believing that no real change in the usages of life would take place, your committee thinks the dates at which the clauses of the proposed act would go into effect are quite unimportant.

As to the educational argument, if children had two five-minute lessons daily in weights and measures, it is certain that one school term would suffice to give scholars a far better acquaintance with both systems than the majority of educated men have now. Since this is done in fact, we must infer that this matter is not held to be vitally important by educators and therefore not so important as America's position in the struggle for trade.

As to the statement that no nation has receded from the metric system, we are informed that on the contrary in France itself the English system of screw threads is now in use, and a struggle is going on which may ultimately result in its exclusive use if the United States maintain their position.

C. S. Peirce,
Wm. Sellers.

Washington, D. C.,
April 17, 1902.

APPENDIX XVII.

Earlier American Reports on the Metric System.

FROM A PAMPHLET ENTITLED "THE COMPULSORY INTRODUCTION OF THE FRENCH METRICAL SYSTEM INTO THE UNITED STATES." PUBLISHED BY WILLIAM SELLERS, 1902.

The report of John Quincy Adams in 1821, and the reports of the University Convocation of the State of New York, 1866 to 1872, originated in the expectation that the French metric system would be adopted, but the investigations of both resulted in its rejection. These show that at no previous period in our history was it believed that the adoption of that system would be advantageous. Since then the development of our mechanic arts has been enormous, and it will not be pretended by any one that a decimal system of metrology would be as desirable in these arts as our binary divisions and our duodecimal measures. It would seem, therefore, that at no future period could it be expected that a purely decimal system of metrology would be acceptable. For this government to adopt alone any modified metric system, would be to provide additional varieties of weights and measures which would probably find few users.

APPENDIX XVIII.

The Purpose and Effect of the Proposed Legislation in Favor of the Metric System.

In March, 1896, the Committee of Coinage, Weights and Measures introduced in the House of Representatives a bill providing:

"1 That from and after the first day of July, 1898, all the departments of the government of the United States, in transaction of all business requiring the use of weight and measurement except in completing the survey of the public lands, shall employ and use only the weights and measures of the metric system.

"2 That from and after the first day of January, 1901, the metric system of weights and measures shall be *the only legal system* of weights and measures recognized in the United States."

The bill introduced in the House of Representatives in 1902, and withdrawn in February, 1903, with the intention of introducing it at the next session of Congress, is the same bill with the dates 1898 and 1901 changed respectively to 1904 and 1907, except that the word "only" in the second clause is omitted, the word "standard" is substituted for "system," and "of and in" for "recognized in."

The difference between the two bills is that the first provides that the metric system shall be "the only legal system," and the second provides that it shall be "the legal standard."

The acknowledged compulsory feature of the bill, namely, that the government must use the metric system (except in the public land surveys) means that all measurements in contracts entered into by private citizens for government work shall be expressed in terms of the metric units. This would cause existing standard sizes to be expressed in equivalent metric terms, with the resulting inconvenience and confusion, or else new specifications, drawings, patterns, gauges, etc. must be prepared to accommodate the sizes to convenient exact metric dimensions. This evidently involves the abandonment of existing standards, a matter of serious importance, especially in the Navy Department.

If any confusion exists in our English system from having too many units of length, weight and volume, the confusion would only be added to by having the government use a different system of measurement from the rest of the people.

FROM AN EDITORIAL IN THE "AMERICAN MACHINIST," MARCH 20, 1903.

Director S. W. Stratton of the National Bureau of Standards, favors the pending bill, but he does not believe in any attempt to make the use of the metric system compulsory nor in the possibility of legislation looking to that end being enforced; but he believes the present bills are beneficent because they provide that after a certain date the United States Government shall become a large buyer of tools and machinery made in accordance with the metric system. Of course, the government will pay for this work, and all who bid upon it will be upon an equal footing, so far as the use of the metric system is concerned, and can make their estimates and bids in accordance with whatever extra expense may be entailed thereby. Thus, then, manufacturers will be paid by the government for the equipment that Mr. Stratton and many others believe will become increasingly necessary or important to the American manufacturer in carrying on his foreign trade.*

The pending bill simply aims to make it commercially advantageous for manufacturers dealing with the United States Government after a certain date to supply articles made to metric measurements. Is there any hardship in that? †

---

* That is, the manufacturer who wishes to do government work will be compelled to invest some of his capital in procuring this necessary equipment, and will, if the government orders a sufficient amount of his products, be paid by the government, that is, by the taxpayers, who provide the funds of the government for such equipment.—W. K.

† The pending bill simply aims to make it commercially disadvantageous for manufacturers who do not wish to provide the equipment necessary to supply articles made to metric measurements. Is not this a hardship?—W. K.

FROM THE OPINION (NON-OFFICIAL) OF ATTORNEY-GENERAL KNOX, FEBRUARY 24, 1902.

(*American Machinist*, March 20, 1903.)

The purpose and effect of each of these bills is to establish the metric system as the legal standard of weights and measures in the United States, and to require all government departments to use only that system, except in completing the survey of the public lands. This comes far short of attempting to compel the people to use only that system, or prohibiting to them the use of any other or making invalid contracts expressed in other terms. Indeed, as each bill prohibits to the departments the use of any other system, by a familiar rule of construction this will be taken as the only prohibition intended, and it will end there.

But a negative answer to your question does not depend upon a mere rule of interpretation, but is based upon much broader grounds. The result referred to—the making contracts illegal for this cause—can be accomplished, if at all, only by clear provision to that effect, and there is nothing of that kind in either of these bills, which, as to this, merely declares that a system different from that now in common use shall be the legal standard. This by no means declares that no other system shall be legal or be used.

The terms, figures and characters in common and almost universal use in our system of weights and measures are just as much parts of the English language as is any other portion of that language, and to forbid to the people their use would require as clear an expression of the legislative will as it would to forbid the use of that language in other matters, even if that would be effective. It may well be doubted if it would be within the competency of Congress to forbid to the people, for this or for any other legitimate purpose, the use of this or any other portion of the language in which our Constitution, our laws and our literature are written, and in which we orally express our thoughts and feelings. I am of opinion that neither of the bills referred to, if enacted into law, would at all affect the legality or validity of any contract thereafter made because expressing its stipulations as to weight or measure in terms other than those of the metric system.

Respectfully,
(Signed) P. C. Knox,
Attorney General.

FROM A PAMPHLET BY WILLIAM SELLERS, 1902,.

What object have the advocates of the metric system for inserting this clause concerning departments in the bill; simply that Congress could enforce the law upon its departments, and the introduction there would react upon the country at large, to induce a more extended use of it. The argument already stated against the destruction of the inch standard, is just as important for the departments of the United States engaged in mechanical pursuits as it is for similar pursuits throughout our country. Such legislation in favor of the French system of metrology, at a time when our mechanics are more than satisfied that our own basis of measurements is superior to the French, is unwise.

APPENDIX XIX.

Concerning Compulsory Legislation.

There is considerable difference of opinion as to whether it was the intention of the framers of the bill before the last Congress that it should make the metric system compulsory upon the people of the United States.

The original bill, introduced in 1896, said: "That from and after the first day of January, 1901, the metric system of weights and measures shall be the only legal system of weights and measures recognized in the United States"; and the bill of 1902 (H. R. No. 123) said the metric system "shall be the legal standard of weights and measures of and in the United States." Attorney-General Knox says "this comes far short of attempting to compel the people to use only that system."

Mr. Southard, Chairman of the Committee of Coinage, Weights and Measures, however, at the hearing before the committee in Washington (see Mr. Halsey's paper, p. 620), said that "the people would have to adopt the system after 1907."

If it was not intended that the system be made compulsory then why was not the last clause, in which the words "the legal standard" occurs, stricken out of the bill?

Mr. Southard was asked this question during the discussion at the New York meeting of the A. S. M. E. (Mr. Halsey's paper, p. 612), and he replied:

"It is possible that the gentleman who introduced the bill thought it might have some effect. I do not suppose there would be any objection to eliminating these words. It certainly can have no effect so far as compelling anybody concerned, and it is a self-evident proposition to me that without some kind of a penalty for a violation of its provisions it could not be deemed compulsory."

If this clause of the bill is not compulsory, and if, as Attorney-General Knox appears to hold, no bill making the metric system the legal standard or the only legal standard can by any act of Congress be made compulsory upon the people, why is not the clause stricken out? Why should Congress be asked to pass a bill which the highest legal authority shows will be a dead letter?

But if the clause is stricken out, what remains of the bill? An act making it compulsory upon the departments of the government to use the metric system after January 1, 1904. And for whose benefit, and for what end? Not for the benefit of the departments or of the government as a whole. They have not asked for the bill. It will confessedly entail upon the government a great expense and trouble, and it will make trouble for every one who bids on a government contract. It will cause the government to use in all its commercial transactions a different language from that of the people.

Why should Congress pass a law, not demanded by the departments or by the people, which will give the government and those who deal with the government so much trouble, with no compensating advantage whatever? Merely because the metric advocates, a very small fraction of the people, who have been conducting a metric propaganda for thirty years, wish the government to undertake the education of the people in a system of weights and measures which the people do not want. They wish as they say to "try it on the dog."

John Quincy Adams, in his report in 1821, said:

The power of the legislator is limited over the will and actions of his subjects. His conflict with them is desperate when he counteracts their settled habits, their established usages, their domestic and individual economy, their ignorance, their prejudices and their wants, all which is unavoidable in the attempt radically to change or to originate a totally new system of weights and measures.

APPENDIX XX.

Conclusions — From Mr. Halsey's Paper.

1 As shown by the experience of other countries, the change of a people's system of weights and measures is a task of enormous difficulty and is attended by widespread confusion. It may then be considered as proven that with us, and especially without general compulsory laws, which the metric advocates disclaim, the transition period will last for a century.

2 The adoption of the metric system involves the destruction of all mechanical standards, meaning by that term the retirement of the inch and the substitution therefor of the millimetre.

3 The prosperity of our foreign trade in no wise requires the adoption of the system as a basis of manufacture.

4 The bill now before Congress is a compulsory measure so far as it relates to those who do business with any of the departments of the government.

APPENDIX XXI.

What is the Use of Further Argument by the Metric Advocates?

There has been more or less agitation of the metric system by its advocates in the United States for over eighty years—ever since 1817, when John Quincy Adams, then Secretary of State, was asked to report to the Senate upon the subject. For the last thirty years the agitation has been acute. Societies have been formed to carry on the agitation, and many bills have been introduced in Congress with the intention of forcing the metric system upon the people of the United States, but with no result except to continue the agitation.

It now appears, according to the opinions of the Attorney-General, of the chairman of the Committee of Coinage, Weights and Measures, and of many of the best informed of the metric advocates that it is not within the power of Congress to enact any valid law making the metric system compulsory on the people of the United States.

It also appears that the people of no nation have ever changed their system of weights and measures voluntarily. The metric system has been brought into use, in those countries which have adopted it, only by compulsory legislation.

The people of the United States have been born and brought up under the English system. It is part of their daily life and habit. No power on earth can force the American carpenter to give up his two-foot rule. He will not give it up of his own free will. English measures of length are "tied irrevocably to the past." The American people cannot give them up if they would.

Even if the metric system were far superior to the English system, which it is not, and even if it were possible to enforce it by compulsory legislation, which it is not, the enormous cost of introducing it, the vast trouble and confusion it would cause during the transition period for at least two generations, the abandonment of our mechanical standards, upon which are based the present system of interchangeability of parts of manufactured articles, the making worthless of the greater portion of our technical literature, make the price too great to pay for any advantages, real or supposed, of the metric system.

The voluntary adoption by the people of the United States of the metric system of weights and measures is no more probable than their adoption of the French language. It cannot be forced on them by law. Further discussion of the subject therefore is merely academic; it can result in nothing practical. Would it not be well now for the metric advocates to drop the subject, and devote their ability and energy to some less visionary reform, such as the improvement of English spelling, or the unification of the coinage and currency of all nations? Too much time has already been wasted in discussion of the metric system. Let the case be closed.

No. 973.*

FINAL REPORT OF THE COMMITTEE APPOINTED TO STANDARDIZE A SYSTEM OF TESTING STEAM ENGINES.†

To The American Society of Mechanical Engineers.

Gentlemen: The undersigned Committee, appointed in June, 1898, to codify and standardize the methods of making engine tests, report as follows:

The ultimate object of an engine test, using the term in its most important sense, is the determination of the economy with which the engine produces a given amount of power. In steam engines the economy, as usually ascertained, relates to the weight of steam consumed, or to the quantity of coal required to make the steam, or to the number of heat units supplied; while in other heat engines it relates to the amount of gas, oil, or other fuel burned. The elementary quantities concerned are thus two in

---

* Presented at the New York meeting (December, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions.*

† For further discussion on this topic consult *Transactions* as follows:

No. 359, vol. xi., p. 72: "Tables of the Properties of Steam. Their Use in Study of Steam-engine Experiments." V. Dwelshauvers-Dery.

No. 381, vol. xi., p. 654: "Report of Committee on a Standard Method of Conducting Duty Trials of Pumping Engines."

No. 381, vol. xii., p. 530: Revised Report as above.

No. 451, vol. xii., p. 790: "Application of Hirn's Analysis to Engine Testing." R. C. Carpenter.

No. 448, vol. xii., p. 740: "Application of Hirn's Analysis to Multiple-expansion Engines." Cecil H. Peabody.

No. 552, vol. xiv., p. 1312: "Report of the Committee on a Standard Method of Conducting Locomotive Tests."

No. 601, vol. xv., p. 1103: "Heat Units, and Specifications for Pumping Engines." A. F. Hall.

No. 781, vol. xix., p. 713: "Plea for a Standard Method of Conducting Engine Tests." Geo. H. Barrus.

No. 786, vol. xix., p. 828: "Extension of the Standard Uniform Methods of Conducting and Reporting Steam-engine Tests." Bryan Donkin.

number; viz., the amount of steam, fuel, or heat, as the case may be, consumed, and the amount of power developed. How to determine these quantities and to systematize the work in such a way as to serve as a standard method of test is the leading problem before us.

It is evident that the standardizing of methods of test should be of such scope as not only to make rules for obtaining the necessary data and working out the results, but to determine a standard form of expressing the results, and standard units in which they should be stated. Furthermore, the scheme proposed should be broad enough to apply to all the principal classes of engines, whatever the nature of their service in practical work, and do this not only in a scientific, but in a practical way, without conflicting with the recommendations of former committees of the Society relating to pumping-engine tests, locomotive tests, and boiler tests. In short, the work of the committee should be one of systematizing the whole subject of engine and steam-plant testing. With this end in view they offer the report of their labors.

1. As a first step, selection must be made of the units upon which the results of a standard test should be based, and the form in which the results should be expressed. The only common ground on which the various classes of heat engines stand is that every one depends for its operation upon the use of heat. Whether employed through the medium of combustion of fuel in a boiler furnace, or combustion in the interior of the engine cylinder, the active energy has its origin in heat. Fuels are proverbially of uncertain quality, whatever their class. Steam boilers are of variable efficiency, even with fuels of identical quality. In a steam engine the weight of steam consumed is an unsatisfactory measure of performance, for the reason that the true thermal economy is affected by the amount of the initial pressure, by the quality of the steam, and by the disposition which is made of the rejected heat of the engine. Measurement on the heat-unit basis takes account of all these variables. It seems to be a foregone conclusion, therefore, that the standard of consumption, not only for steam engines, but for all classes of heat engines, should be referred to heat units.

The unit of mechanical power almost universally adopted is the "horse-power," and by common agreement it is a satisfactory unit expressive of the power developed by an engine. If it were possible in every case to determine the useful power delivered by an engine, or what is termed in some instances the "brake horse-power," there would be good ground for making the unit the delivered power; but such determinations are rarely feasible. On the other hand, it is not always possible to obtain the indicated horse-power, as, for example, in the case of steam turbines. It is, therefore, necessary to employ two units of power; viz., the indicated and the brake horse-power.

The expressions of engine economy which meet all the requirements noted are the number of heat units consumed per hour, both per indicated and per brake horse power, and these we recommend as the desired standards of comparison. The heat-unit standard does not interfere in any way with the common terms of expressing economy of engines. The hourly weights of coal, gas, oil, or other fuel, or weight of steam consumed per horse-power, heretofore commonly employed, are additional forms of stating economy, and are none the less useful within their limitations. They should by no means be abandoned. Neither should the standard forms recommended for expressing the duty of pumping engines, or the efficiency of locomotives, previously accepted by the Society, be changed, as they do not conflict with the proposed new standard. In the scheme now presented by your Committee these additional or subsidiary forms of stating economy, as applied to particular classes of engines, are suitably provided for.

The heat-unit expression of economy does not in itself show whether the engine is working to its best advantage any more than the expression of the steam consumption; this must be determined by an analysis of the conditions as to initial and final pressures, cut-off, etc., under which the engine works.

2. The heat consumption of a steam-engine plant required for the standard test is ascertained by measuring the quantity of steam consumed by the plant, calculating the total heat of the entire quantity, and crediting this total with that portion of the heat rejected by the plant, which is utilized and returned to the boiler. The term "engine plant" as here used should include the entire equipment of the steam plant which is concerned in the production of the power, embracing the main cylinder or cylinders; the jackets and reheaters; the air, circulating, and boiler feed pumps, if steam driven; and any other steam-driven mechanism or auxiliaries necessary to the working of the engine. It is obligatory

to thus charge the engine with the steam used by necessary auxiliaries in determining the plant economy, for the reason that it is itself finally benefited, or should be so benefited, by the heat which they return; it being generally agreed that exhaust steam from such auxiliaries should be passed through a feed-water heater, and the heat thereby carried back to the boiler and saved.

The heat consumption of gas and oil engines of the internal combustion class is found by ascertaining the total heat of combustion of the particular fuel used, which should be determined by a calorimeter test, and multiplying the result by the quantity of fuel consumed. In determining the total heat of combustion, no deduction is made for the latent heat of the water vapor in the products of combustion.

3. The indicated horse-power for the proposed standard is that determined by the use of steam-engine indicators. It should be confined to the power developed in the main cylinder or cylinders, and should not include that developed in the cylinders of auxiliaries.

We do not recommend any special make of indicator or special method of applying and operating the instrument. It is of the greatest importance that the indicator itself and the mode of using it shall be correct and pass the necessary test for reliability demanded by correct work.

4. We have given due attention to the report of the committee appointed by the Institution of Civil Engineers, of London, to consider and report upon the subject of the "Definition of a Standard or Standards of Thermal Efficiency for Steam Engines," published in *Proceedings*, 1898, which recommends a heat-unit standard similar to that proposed by your Committee. The British standard takes no account of the steam used by steam-driven auxiliaries, and it assumes the ideal condition that the heat rejected by the engine and returned to the boiler is that corresponding to the pressure of the steam in the exhaust pipe, irrespective of the actual means employed for utilizing the rejected heat. This basis of efficiency furnishes a useful means of comparing the economy of different engines in themselves, and of the same engine under different conditions, all questions regarding auxiliaries and the efficiency of appliances used for heating the feed water being treated separately.

We have embodied the British standard in this code, but we consider that in most cases sufficient accuracy will be obtained by taking the heat returned to the boiler as that corresponding to the temperature of steam at the pressure of the atmosphere for non-condensing engines, and to the vacuum in the condenser for condensing engines, in place of that corresponding to the pressure in the exhaust pipe.

5. We have chosen as one of the important subsidiary forms of expressing efficiency that based on a so-called "standard coal" unit. The assumption is made that the heat consumed by the engine is generated from coal of a fixed heat value, as implied by the term "standard coal."

The term "standard coal" refers to a coal which imparts to the steam 10,000 British thermal units for each pound of the dry coal consumed. It is coal having a calorific value of 12,500 British thermal units used in what may be termed a "standard boiler," which gives an efficiency of 80 per cent. (referred to the coal). Although chosen arbitrarily, these figures, as a matter of fact, apply closely to the average coals of the United States, and, furthermore, the latter figure is in accord with that adopted by the Locomotive Test Committee.

6. In carrying forward our work, the general plan followed is: first, to satisfy the special object in view, that is, to lay down the form of test which shall serve as a standard for all steam engines, whatever their service, viz., the heat-unit test; second, to supplement the standard system thus framed with provisions for systematically determining other forms of expressing efficiency of steam engines, as in cases where it is desired to base the economy on the steam or fuel consumption; third, and as a further supplement, to standardize the methods of testing steam engines and results obtained with reference to their particular service, so far as this has not heretofore been accomplished; and fourth, to systematize the work of testing gas, oil, and other internal combustion engines. The tables of data and results which are recommended are planned accordingly.

Although engine testing is a species of scientific investigation, we have kept in mind the fact that the one thing of highest importance is the practical result secured, not alone by the engine, but by the auxiliaries as well. We have thus viewed the subject from the standpoint of the owner and user. At the same time we have endeavored to secure a plan of such breadth that whatever the special object of the engine test, whether it be a scientific investigation, a practical determination of every-day performance in the interest solely of the owner of the engine, who must defray the expenses of its operation, or a test in the interest of the engine builder, with the object of showing the capability of the machine and using this information for purposes of advertising and trade, it will prove sufficient and suitable for all.

7. To make the work complete, attention has been given to the subject of commercial tests of steam engines; that is, to coal tests of the combined engine and boiler under conditions of commercial use. Such tests are of the greatest importance to the user of a plant, and they demand consideration.

8. In treating of the subject of engine testing as relating primarily tó the determination of matters of economy, it must not be forgotten that capacity is often of even greater importance than economy. In that large class of steam engines which are required to run at a certain limited and constant speed, there should be a considerable reserve of capacity beyond the rated power. It is our recommendation that when a steam engine is operating at its rated power at a given pressure there should be a sufficient reserve to allow a drop of at least 15 per cent. in the gauge pressure without sensible reduction in the working speed of the engine, and to allow an overload at the stated pressure amounting to at least 25 per cent.

9. Having thus briefly referred to the leading features of the work, the Committee beg to submit their conclusions in the following Code of Rules and Tables.

Respectfully submitted,

GEORGE H. BARRUS,
FRANCIS H. BOYER,
BRYAN DONKIN,*
D. S. JACOBUS,
GEORGE RICHMOND,
Committee.

* Mr. Donkin took a great interest in the work of preparing this report. His signature was attached to the first two prelimary forms which were presented at meetings of the Society, and he kept in close touch by correspondence with the other members of the Committee in their work of final revision until shortly before his death, which occurred on March 2, 1902.

RULES FOR CONDUCTING STEAM-ENGINE TESTS. CODE OF 1902.

I. Object of Test.—Ascertain at the outset the specific object of the test, whether it be to determine the fulfilment of a contract guarantee, to ascertain the highest economy obtainable, to find the working economy and defects under conditions as they exist, to ascertain the performance under special conditions, to determine the effect of changes in the conditions, or to find the performance of the entire boiler and engine plant, and prepare for the test accordingly.

No specific rules can be laid down regarding many of the preparations to be made for a test, so much depends upon the local conditions; and the matter is one which must be left mainly to the good sense, tact, judgment, and ingenuity of the party undertaking it. One guiding principle must ever be kept in mind; namely, to obtain data which shall be thoroughly reliable for the purposes in view. If questions of contract are to be settled, it is of the first importance that a clear understanding be had with all the parties to the contract as to the methods to be pursued—putting this understanding, if necessary, in writing —unless these are distinctly provided for in the contract itself. The preparations for the measurement of the feed water and of the various quantities of condensed water in the standard heat-unit test should be made in such a manner as to change as little as possible the working conditions and temperatures of the plant.

II. General Condition of the Plant.—Examine the engine and the entire plant concerned in the test; note its general condition and any points of design, construction, or operation which bear on the objects in view. Make a special examination of the valves and pistons for leakage by applying the working pressures with the engine at rest, and observe the quantity of steam, if any, blowing through per hour.

If the trial has for an object the determination of the highest efficiency obtainable, the valves and pistons must first be made tight, and all parts of the engine and its auxiliaries, and all other parts of the plant concerned, should be put in the best possible working condition.

The method of testing the valves and pistons for leakage in a Corliss engine, or one in which the admission valves can be operated independently of the exhaust valves, is as follows: close the two steam valves, open the two indicator cocks, and admit a full pressure of steam into the chest by opening the throttle valve. The movement of the starting bar, first one way and then the other, so as to close one exhaust valve and then the other, causes the leakage through the steam valves to escape from the open indicator cock, where it becomes visible. The quantity of leakage is judged by the force of the current of steam blowing out.

To test the exhaust valves and piston, the best method is to block the flywheel so that the piston will be at a short distance from the end of the stroke, and turn on the steam. The leakage escapes to the exhaust pipe, and can be observed at the open atmospheric outlet. If the outlet is not visible, and there is a valve in the exhaust pipe, this can be shut and the indicator cock opened, thereby deflecting the steam which leaks, and causing it to appear at the indicator cock. In the case of a condensing engine where no atmospheric pipe is provided, and there is no opening that can be made in the exhaust pipe in front of the condenser, some idea can be obtained in regard to the amount of leakage by observing how rapidly the condenser is heated. It is well to make these tests with the piston in different positions, so as to cover the whole range of the length of the stroke.

Another but more approximate method of testing leakage is called the "time method." Instead of observing the steam that actually blows through the valves or piston to be tested, they are subjected to full steam pressure, and when the parts are thoroughly heated, the throttle valve is shut and the length of time observed which is required for the pressure to disappear. In testing the piston and exhaust valves, the flywheel is blocked as before, and, preferably, an indicator is attached, and a line drawn on a blank card at intervals of, say, one-quarter of a minute after the valve is shut, thereby making a record of the fall of the pressure. In a tight engine the fall of the pressure is slow, whereas in a leaky engine it is sometimes very rapid. The relative condition of the engine as compared with a tight engine must be judged by an observer, who must, of course, have had experience in tests of this kind on engines in various conditions.

The leakage of a piston can always be determined by removing the cylinder head and observing what blows through the open end with the pressure of steam behind it. The advantage of the "time method" is that it saves the labor and time required in removing the cylinder head and replacing it, which, in cases of large engines, is considerable.

Leakage tests of single-valve engines cannot be made as satisfactorily as those of the Corliss type and other four-valve engines. The best that can be done as regards the valve is to place it at or near the centre of its travel, covering both ports, and then make the test under full pressure. The valve and piston can be tested as a whole by blocking the flywheel and opening the throttle valve in the same way as in other engines.

In testing compound engines for leakage, the work is somewhat simplified in case of any one cylinder, as compared with a single engine. For example, leakage of the high-pressure cylinder can be revealed by opening the indicator cock on the proper end of the low-pressure cylinder, the steam valve of that cylinder being open. The test of leakage of the low-pressure exhaust valves and piston when the "time method" is used can be based on the indications of the receiver gauge instead of using an indicator. In that case the fall of the pressure due to leakage is read directly from the gauge.

The tests thus far referred to are qualitative, and not quantitative. It is practical in some cases to determine the quantity of leakage under any set of conditions by collecting the steam which passes through, condensing it and weighing it. This can be readily done when there is a surface condenser, and it can be done in the absence of such a condenser by attaching a small pipe to the exhaust, and carrying the steam which escapes into a tank of water and condensing it. How much dependence can be placed upon the results of such a quantitative test as showing the actual quantity of leakage which occurs when the valves and pistons are in motion must be left to the judgment of the person who makes the test.

When full information is desired, it is well to test the valves and pistons in several different positions, so as to cover the whole range of action.

In Corliss engines the leakage of the piston with the engine in operation can be observed by removing the cylinder head, disconnecting the steam and exhaust valves at the head end, and setting the engine to work with steam admitted at the crank end.

III. DIMENSIONS, ETC.—Measure or check the dimensions of the cylinders in any case, this being done when they are hot. If they are much worn, the average diameter should be determined. Measure also the clearance, which should be done, if possible, by filling the spaces with water previously measured, the piston being placed at the end of the stroke. If the clearance cannot be measured directly, it can be determined approximately from the working drawings of the cylinder.

Measure also the dimensions of auxiliaries and accessories, also those of the boilers so far as concerned in attaining the objects. It is well to supplement these determinations with a sketch or sketches showing the general features and arrangement of the different parts of the plant.

To measure the clearance by actual test, the engine is carefully set on the centre, with the piston at the end where the measurement is to be taken. Assuming, for example, a Corliss engine, the best method to pursue is to remove the steam valve so as to have access to the whole steam port, and then fill up the clearance space with water, which is poured into the open port through a funnel. The water is drawn from a receptacle containing a sufficient quantity, which has previously been measured. When the whole space, including the port, is completely filled, the quantity left is measured, and the difference shows the amount which has been poured in. The measurement can be most easily made by weighing the water, and the corresponding volume determined by calculation, making proper allowance for its temperature. The proportion required is the volume in cubic inches thus found, divided by the volume of the piston displacement, also in cubic inches, and the result expressed as a decimal. In this test care should be taken that no air is retained in the clearance space when it is filled with water.

The only difficulty which arises in measuring the clearance in this way is that occurring when the exhaust valves and piston are not tight, so that, as the water is poured in, it flows away and is lost. If the leakage is serious, no satisfactory measurement can be made, and it is better to depend upon the volume calculated from the drawing. If not too serious, however, an allowance can be made by carefully observing the length of time consumed in pouring in the water; then, after a portion of the water has leaked out, fill up the space again, taking the time, and measuring the quantity thus added, determining in this way the rate at which the leakage occurs. Data will thus be obtained for the desired correction.

IV. COAL.—When the trial involves the complete plant, embracing boilers as well as engine, determine the character of coal to be used. The class, name of the mine, size, moisture, and quality of the coal should be stated in the report. It is desirable, for purposes of comparison, that the coal should be of some recognized standard quality for the locality where the plant is situated.

For New England and that portion of the country east of the Allegheny Mountains, good anthracite egg coal, containing not over 10 per cent. of ash, and semi-bituminous Clearfield (Pa.), Cumberland (Md.), and Pocahontas (Va.) coals are thus regarded. West of the Allegheny Mountains, Pocahontas (Va.) and New River (W. Va.) semi-bituminous and Youghiogheny or Pittsburg bituminous coals are recognized as standards. (*Transactions A. S. M. E.*, vol. xxi., p. 38.)

V. CALIBRATION OF INSTRUMENTS.—All instruments and apparatus should be calibrated and their reliability and accuracy verified by comparison with recognized standards. Such apparatus as is liable to change or become broken during a test, as gauges, indicator springs, and thermometers, should be calibrated before and after the test. The accuracy of scales should be verified by standard weights. When a water meter is used, special attention should be given to its calibration, verifying it both before and after the trial, and, if possible, during its progress, the conditions in regard to water pressure and rate of flow being made the same in the calibrations as exist throughout the trial.

(*a*) GAUGES.—For pressures above the atmosphere, one of the most convenient, and at the same time reliable, standards is the dead-weight testing apparatus which is manufactured by many of the prominent gauge makers. It consists of a vertical plunger nicely fitted to a cylinder containing oil or glycerine, through the medium of which the pressure is transmitted to the gauge. The plunger is surmounted by a circular stand on which weights may be placed, and by means of which any desired pressure can be secured. The total weight, in pounds, on the plunger at any time, divided by the average area of the plunger and of the bushing which receives it, in square inches, gives the pressure in pounds per square inch.

Another standard of comparison for pressures is the mercury column. If this instrument is used, assurance must be had that it is properly graduated with reference to the ever-varying zero point; that the mercury is pure, and that the proper correction is made for any difference of temperature that exists, compared with the temperature at which the instrument was graduated.

For pressures below the atmosphere, an air pump or some other means of producing a vacuum is required, and reference must be made to a mercury gauge. Such a gauge may be a U-tube having a length of 30 inches or so, with both arms properly filled with pure mercury.

(*b*) Thermometers.—Standard thermometers are those which indicate 212 degrees Fahr. in steam escaping from boiling water at the normal barometrical pressure of 29.92 inches, the whole stem up to the 212-degree point being surrounded by the steam; and which indicate 32 degrees Fahr. in melting ice, the stem being likewise completely immersed to the 32-degree point; and which are calibrated for points between and beyond these two reference marks. We recommend, for temperatures between 212 degrees and 400 degrees Fahr., that the comparison of the thermometer be made with the temperature given in Regnault's Steam Tables, the method required being to place it in a mercury well surrounded by saturated steam under sufficient pressure to give the desired temperature. The pressure should be accurately determined as pointed out in the above section (*a*), and the thermometer should be immersed to the same extent as it is under its working condition.

Thermometers in practice are seldom used with the stems fully immersed; consequently, when they are compared with the standard, the comparison should be made under like conditions, and practically under the working conditions, whatever those happen to be.

If pyrometers of any kind are used, they should be compared with a mercury thermometer within its range, and if extreme accuracy is required, with an air thermometer, or a standard based thereon, at higher points, care being taken that the medium surrounding the pyrometer, be it air or liquid, is of the same uniform temperature as that surrounding the standard.

(*c*) Indicator Springs.—(See Section XIV.)

(*d*) Water Meters.—A good method of calibrating a water meter is the following, reference being made to Fig. 118:

Two tees *A* and *B* are placed in the feed pipe, and between them two valves *C* and *D*. The meter is connected between the outlets of the tees *A* and *B*. The valves *E* and *F* are placed one on each side of the meter. When the meter is running, the valves *E* and *F* are opened, and the valves *C* and *D* are closed. Should an accident happen to the meter during the test, the valves *E* and *F* may be closed, and the valves *C* and *D* opened, so as to allow the feed water to flow directly into the boiler. A small bleeder *G* is placed between the valves *C* and *D*. The valve *G* is opened when the valves *C* and *D* are closed, in order to make sure that there is no leakage. A gauge is attached at *H*. When the meter is tested, the valves *C*, *D*, and *F* are closed, and the valves E and I are opened. The water flows from the valve I to a tank placed on weighing scales. In testing the meter the feed pump is run at the normal speed, and the water leaving the meter is throttled at the valve I until the pressure shown by the gauge H is the same as that indicated when the meter is running under the normal conditions. The piping leading from the valve I to the tank is arranged with a swinging joint, consisting merely of a loosely fitting elbow, so that it can be readily turned into the tank or away from it. After the desired pressure and speed have been secured, the end of the pipe is swung into the tank the instant that the pointer of the meter is opposite some graduation mark on the dial, and the water continues to empty into the tank while any desired number of even cubic feet are discharged, after which the pipe is swung away from the tank. The tests should be made by starting and stopping at the same graduation mark on the

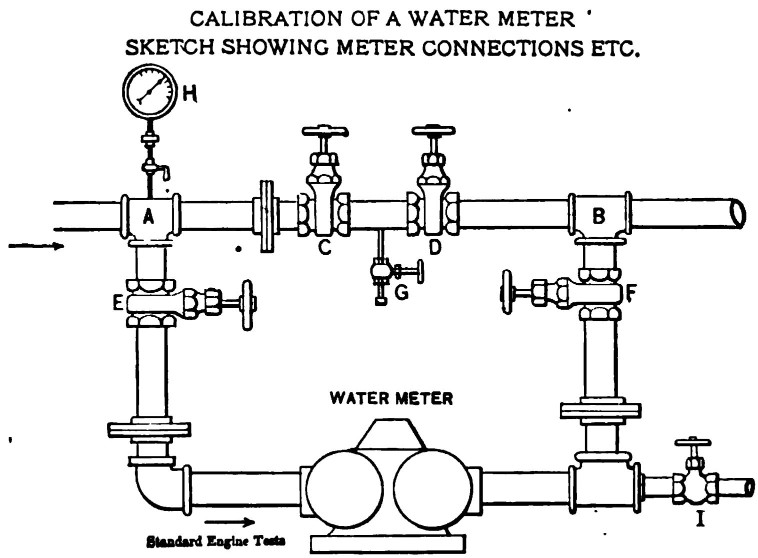


FIG. 118.

meter dial, and continued until at least 10 or 20 cubic feet are discharged for one test. The water collected in the tank is then weighed.

The water passing the meter should always be under pressure in order that any air in the meter may be discharged through the vents provided for this purpose. Care should be taken that there is no air contained in the feed water. Should the feed-water pump draw from a hot-well, the height of the water in the hot-well must never be as low as the suction pipe of the pump. In case the speed of the feed pump cannot be regulated, as occurs in some cases where it is driven directly from the engine, a by-pass should be connected with the pipe leading from the pump, to allow some of the water to flow back into the hot-well, if the pump lowers the water in the hot-well beyond a given mark. The meter should be tested both before and after the engine trial, and several tests should be made of the meter in each case in order to obtain confirmative results. It is well to make preliminary tests to determine whether the meter works satisfactorily before connecting it up for an engine trial. The results should agree with each other for two widely different rates of flow.

VI. LEAKAGES OF STEAM, WATER, ETC.—In all tests except those of a complete plant made under conditions as they exist, the boiler and its connections, both steam and feed, as also the steam piping leading to the engine and its connections, should, so far as possible, be made tight. If absolute tightness cannot be obtained (in point of fact it rarely can be), proper allowance should be made for such leakage in determining the steam actually consumed by the engine. This, however, is not required where a surface condenser is used and the water consumption is determined by measuring the discharge of the air pump. In such cases it is necessary to make sure that the condenser is tight, both before and after the test, against the entrance of circulating water, or if such occurs to make proper correction for it, determining it under the working difference of pressure. Should there be excessive leakage of the condenser it should be remedied before the test is made. When the steam consumption is determined by measuring the discharge of the air pump, any leakage about the valve or piston rods of the engine should be carefully guarded against.

Make sure that there is no leakage at any of the connections with the apparatus provided for measuring and supplying the feed water which could affect the results. All connections should, so far as possible, be visible and be blanked off, and where this cannot be done, satisfactory assurance should be obtained that there is no leakage either in or out.

It is not always necessary to blank off a connecting pipe to make sure that there is no leakage through it. If satisfactory assurance can be had that there is no chance for leakage, this is sufficient. For example, where a straightway valve is used for cutting off a connecting pipe, and this valve has double seats with a hole in the bottom between them, this being provided with a plug or pet cock, assurance of the tightness of the valve when closed can be had by removing the plug or opening the cock. Likewise, if there is a drain pipe beyond the valve, the fact that no water escapes here is sufficient evidence of the tightness of the valve. The main thing is to have positive evidence in regard to the tightness of the connections, such as may be obtained by the means suggested above ; but where no positive evidence can be obtained, or where the leakage that occurs cannot be measured, it is of the utmost importance that the connections should be broken and blanked off.

Leakage of relief valves which are not tight, drips from traps, separators, etc., and leakage of tubes in the feed water-heater must all be guarded against or measured and allowed for.

It is well, as an additional precaution, to test the tightness of the feed-water pipes and apparatus concerned in the measurement of the water by running the pump at a slow speed for, say, fifteen minutes, having first shut the feed valves at the boilers. Leakage will be revealed by disappearance of water from the supply tank. In making this test, a gauge should be placed on the pump discharge in order to guard against undue or dangerous pressure.

To determine the leakage of steam and water from a boiler and steam pipes, etc., the *water-gauge glass* method may be satisfactorily employed. This consists in shutting off all the feed valves (which must be known to be tight) or the main feed valve, thereby stopping absolutely the entrance or exit of water at the feed pipes to the boiler; then maintaining the steam pressure (by means of a very slow fire) at a fixed point, which is approximately that of the working pressure, and observing the rate at which the water falls in the gauge glasses. It is well, in this test, as in other work of this character, to make observations every ten minutes, and to continue them for such a length of time that the differences between successive readings attain a constant rate. Generally the conditions will have become constant at the expiration of fifteen minutes from the time of shutting the valves, and thereafter the fall of water due to leakage of steam and water becomes approximately constant. It is usually sufficient, after this time, to continue the test for one hour, thereby taking six ten-minute readings. When this test is finished, the quantity of leakage is ascertained by calculating the volume of water which has disappeared, using the area of the water level and the depth shown on the glass, making due allowance for the weight of one cubic foot of water at the observed pressure. If possible, the gauge glass for this test should be attached close to the boiler.

If there is opportunity for much condensation to occur and collect in the steam pipe during the leakage test, the quantity should be determined as closely as desirable, and properly allowed for.

In making a test of an engine where the steam consumption is determined from the amount of water discharged from the surface condenser, leakage of the piston rods and valve rods should be guarded against; for if these are excessive, the test is of little use, as the leakage consists partly of steam that has already done work in the cylinder and of water condensed from the steam when in contact with the cylinder. If such leakage cannot be prevented, some allowance should be made for the quantity thus lost. The weight of water as shown at the condenser must be increased by the quantity allowed for this leakage.

VII. DURATION OF TEST.—The duration of a test should depend largely upon its character and the objects in view. The standard heat test of an engine, and, likewise, a test for the simple determination of the feed-water consumption, should be continued for at least five hours, unless the class of service precludes a continuous run of so long duration. It is desirable to prolong the test the number of hours stated to obtain a number of consecutive hourly records as a guide in analyzing the reliability of the whole.

Where the water discharged from the surface condenser is measured for successive short intervals of time, and the rate is found to be uniform, the test may be of a much shorter duration than where the feed water is measured to the boiler. The longer the test with a given set of conditions, the more accurate the work, and no test should be so short that it cannot be divided into several intervals which will give results agreeing substantially with each other.

The commercial test of a complete plant, embracing boilers as well as engine, should continue at least one full day of twenty four hours, whether the engine is in motion during the entire time or not. A continuous coal test of a boiler and engine should be of at least ten hours' duration, or the nearest multiple of the interval between times of cleaning fires.

VIII. STARTING AND STOPPING A TEST.—(*a*) *Standard Heat Test and Feed Water Test of Engine:* The engine having been brought to the normal condition of running, and operated a sufficient length of time to be thoroughly heated in all its parts, and the measuring apparatus having been adjusted and set to work, the height of water in the gauge glasses of the boilers is observed, the depth of water in the reservoir from which the feed water is supplied is noted, the exact time of day is observed, and the test held to commence. Thereafter the measurements determined upon for the test are begun and carried forward until its close. If practicable, the test may be commenced at some even hour or minute, but it is of the first importance to begin at such time as reliable observations of the water heights are obtained, whatever the exact time happens to be when these are satisfactorily determined. When the time for the close of the test arrives, the water should, if possible, be brought to the same height in the glasses and to the same depth in the feed-water reservoir as at the beginning, delaying the conclusion of the test if necessary to bring about this similarity of conditions. If differences occur, the proper corrections must be made.

Care should be taken in cases where the activity of combustion in the boiler furnaces affects the height of water in the gauge glasses that the same condition of fire and draughts are operating at one time as at the other. For this reason it is best to start and stop a test without interfering with the regularity of the operation of the feed pump, provided the latter may be regulated to run so as to supply the feed water at a uniform rate. In some cases where the supply of feed water is irregular, as, for example, where an injector is used of a larger capacity than is required, the supply of feed water should be temporarily shut off.

It is important to use great care in obtaining the average height of the water in the glasses, taking sufficient time to satisfactorily judge of the full extent of the fluctuation of the water line, and thereby its mean position. It is important, also, to refrain from blowing off the water column or its connecting pipes, either during the progress of the test or for a period of an hour or more prior to its beginning. Such blowing off changes the temperature of the water within, and thereby its specific gravity and height.

To mark the height of water in a gauge glass in a convenient way, a paper scale, mounted on wood and divided into tenths of inches, may be placed behind it or at its side.

(*b*) *Complete Engine and Boiler Test:* For a continuous running test of combined engine or engines, and boiler or boilers, the same directions apply for beginnin and ending the feed-water measurements as that just referred to under Section (*a*). The time of beginning and ending such a test should be the regular time of cleaning the fires, and the exact time of beginning and ending should be the time when the fires are fully cleaned, just preparatory to putting on fresh coal. In cases where there are a number of boilers, and it is inconvenient or undesirable to clean all fires at once, the time of beginning the test should be deferred until they are all cleaned and in a satisfactory state, all the fires being then burned down to a uniformly thin condition, the thickness and condition being estimated and the test begun just before firing the new coal previously weighed. The ending of the test is likewise deferred until the fires are all satisfactorily cleaned, being again burned down to the same uniformly thin condition as before, and the time of closing being taken just before replenishing the fires with new coal.

For a commercial test of a combined engine and boiler, whether the engine runs continuously for the full twenty-four hours of the day, or only a portion of the time, the fires in the boilers being banked during the time when the engine is not in motion, the beginning and ending of the test should occur at the regular time of cleaning the fires, the method followed being that already given. In cases where the engine is not in continuous motion, as, for example, in textile mills, where the working time is ten or eleven hours out of the twenty-four, and the fires are cleaned and banked at the close of the day's work, the best time for starting and stopping a test is the time just before banking, when the fires are well burned down and the thickness and condition can be most satisfactorily judged. In these, as in all other cases noted, the test should be begun by observing the exact time, the thickness and condition of the fires on the grates, the height of water in the gauge glasses of the boilers, the depth of the water in the reservoir from which the feed water is supplied, and other conditions relating to the trial, the same observations being again taken at the end of the test, and the conditions in all respects being made as nearly as possible the same as at the beginning.

IX. MEASUREMENT OF HEAT UNITS CONSUMED BY THE ENGINE.—The measurement of the heat consumption requires the measurement of each supply of feed water to the boiler—that is, the water supplied by the main feed pump, that supplied by auxiliary pumps, such as jacket water, water from separators, drips, etc., and water supplied by gravity or other means; also the determination of the temperature of the water supplied from each source, together with the pressure and quality of the steam.

The temperatures at the various points should be those applying to the working conditions. The temperature of the feed water should be taken near the boiler. This causes the engine to suffer a disadvantage from the heat lost by radiation from the pipes which carry the water to the boiler, but it is, nevertheless, advisable on the score of simplicity. Such pipes would, therefore, be considered a portion of the engine plant. This conforms with the rule already recommended for the tests of pumping engines where the duty per million heat units is computed from the temperature of the feed water taken near the boiler. It frequently happens that the measurement of the water requires a change in the usual temperature of supply. For example, where the main supply is ordinarily drawn from a hot-well in which the temperature is, say, 100 degrees Fahr., it may be necessary, owing to the low level of the well, to take the supply from some source under a pressure or head sufficient to fill the weighing tanks used, and this supply may have a temperature much below that of the hot-well; possibly as low as 40 degrees Fahr. The temperature to be used is not the temperature of the water as weighed in this case, but that of the working temperature of the hot-well. The working temperature in cases like this must be determined by a special test, and included in the log sheets.

In determining the working temperatures, the preliminary or subsequent test should be continued a sufficient time to obtain uniform indications, and such as may be judged to be an average for the working conditions. In this test it is necessary to have some guide as to the quantity of work being done, and for this reason the power developed by the engine should be determined by obtaining a full set of diagrams at suitable intervals during the progress of the trial. Observations should also be made of all the gauges connected with the plant and of the water heights in the boilers, the latter being maintained at a uniform point so as to be sure that the rate of feeding during the test is not sensibly different from that of the main test.

The heat to be determined is that used by the entire engine equipment, embracing the main cylinders and all auxiliary cylinders and mechanism concerned in the operation of the engine, including the air pump, circulating pump, and feed pumps, also the jacket and reheater when these are used. No deduction is to be made for steam used by auxiliaries unless these are shown by test to be unduly wasteful. In this matter an exception should be made in cases of guarantee tests where the engine contractor furnishes all the auxiliaries referred to. He should, in that case, be responsible for the whole, and no allowance should be made for inferior economy, if such exists. Should a deduction be made on account of the auxiliaries being unduly wasteful, the method of waste and its extent, as compared with the wastes of the main engine or other standard of known value, shall be reported definitely.

The steam pressure and the quality of the steam are to be taken at some point conveniently near the throttle valve. The quantity of steam used by the calorimeter must be determined and properly allowed for. (See Article XVI., on "Quality of Steam.")

X. Measurement of Feed Water or Steam Consumption of Engine, Etc.—The method of determining the steam consumption applicable to all plants is to measure all the feed water supplied to the boilers, and deduct therefrom the water discharged by separators and drips, as also the water and steam which escapes on account of leakage of the boiler and its pipe connections and leakage of the steam main and branches connecting the boiler and the engine. In plants where the engine exhausts into a surface condenser the steam consumption can be measured by determining the quantity of water discharged by the air pump, corrected for any leakage of the condenser, and adding thereto the steam used by jackets, reheaters, and auxiliaries as determined independently. If the leakage of the condenser is too large to satisfactorily allow for it, the condenser should, of course, be repaired and the leakage again determined before making the test.

In measuring the water it is best to carry it through a tank or tanks resting on platform weighing scales suitably arranged for the purpose, the water being afterwards emptied into a reservoir beneath, from which the pump is supplied.

The simplest apparatus of this kind, having a capacity of say 6,000 pounds of water per hour, consists of a small hogshead connected to the suction pipe of the pump or injector, and an ordinary oil barrel mounted on a platform-scale, the latter being supported by the hogshead on one side, and by a suitable staging on the other side. The barrel is filled by means of a cold-water pipe leading from the source of supply, and this should be a 1½-inch pipe for pressures not less than 25 pounds per square inch. The outlet valve of the barrel is attached to the side, close to the bottom, and should be at least 2½ inches in diameter for quick emptying. Where large quantities of water are required, the barrel can be replaced by a hogshead, and two additional hogsheads can be coupled together for the lower reservoir. The capacity reached by this arrangement when the weighing hogshead is supplied through a 2½-inch valve under 25 pounds pressure and emptied through a 5-inch valve, is 15,000 pounds of water per hour. For still larger capacity, it is desirable to use rectangular tanks made for the purpose, and have the weighing tank arranged so that the ends overhang the scales and the reservoir below; the outlet valve, consisting of a flap valve, covering an opening in the bottom 6 or 8 inches square. With rectangular tanks this system can be employed for any size of stationary engine ordinarily met with.

Where extremely large quantities of water must be measured, or in some places relatively small quantities, the orifice method of measuring is one that can be applied with satisfactory results. In this case the average head of water on the orifice must be determined, and, furthermore, it is important that means should be at hand for calibrating the discharge of the orifice under the conditions of use.

The corrections or deductions to be made for leakage above referred to should be applied only to the standard heat-unit test and tests for determining simply the steam or feed water consumption, and not to coal tests of combined engine and boiler equipment. In the latter, no correction should be made except for leakage of valves connecting to other engines and boilers, or for steam used for purposes other than the operation of the plant under test. Losses of heat due to imperfections of the plant should be charged to the plant, and only such losses as are concerned in the working of the engine alone should be charged to the engine.

In measuring jacket water or any supply under pressure which has a temperature exceeding 212 degrees Fahr., the water should first be cooled, as may be done by discharging it into a tank of cold water previously weighed, or by passing it through a coil of pipe submerged in running and colder water, preventing thereby the loss of evaporation which occurs when such hot water is discharged into the open air.

XI. Measurement of Steam Used by Auxiliaries.—Although the steam used by the auxiliaries—embracing the air pump, circulating pump, feed pump, and any other apparatus of this nature, supposing them to be steam-driven, also the steam jackets, reheaters, etc., which consume steam required for the operation of the engine—is all included in the measurement of the steam consumption, as pointed out in Article X., yet it is highly desirable that the quantity of steam used by the auxiliaries, and in many cases that used by each auxiliary, should be determined exactly, so that the net consumption of the main engine cylinders may be ascertained and a complete analysis made of the entire work of the engine plant. Where the auxiliary cylinders are non-condensing, the steam consumption can often be measured by carrying the exhaust for the purpose into a tank of cold water resting on scales or through a coil of pipe surrounded by cold running water. Another method is to run the auxiliaries as a whole, or one by one, from a spare boiler (preferably a small vertical one), and measure the feed water supplied to this boiler. The steam used by the air and circulating pumps may be measured by running them under, as near as possible, the working conditions and speed, the main engine and other auxiliaries being stopped, and testing the consumption by the measuring apparatus used on the main trial. For a short trial, to obtain approximate results, measurement can be made by the water-gauge glass method, the feed supply being shut off. When the engine has a surface condenser, the quantity of steam used by the auxiliaries may be ascertained by allowing the engine alone to exhaust into the condenser, measuring the feed water supplied to the boiler and the water discharged by the air pump, and subtracting one from the other, after allowing for losses by leakage.

XII. COAL MEASUREMENT.—(*a*) *Commercial Tests:* In commercial tests of the combined engine and boiler equipment, or those made under ordinary conditions of commercial service, the test should, as pointed out in Article VII., extend over the entire period of the day; that is, twenty-four hours, or a number of days of that duration. Consequently, the coal consumption should be determined for the entire time. If the engine runs but a part of the time, and during the remaining portion the fires are banked, the measurement of coal should include that used for banking. It is well, however, in such cases, to determine separately the amount consumed during the time the engine is in operation and that consumed during the period while the fires are banked, so as to have complete data for purposes of analysis and comparison, using suitable precautions to obtain reliable measurements. The measurement of coal begins with the first firing, after cleaning the furnaces and burning down at the beginning of the test, as pointed out in Article VIII., and ends with the last firing, at the expiration of the allotted time.

(*b*) *Continuous Running Tests:* In continuous running tests which, as pointed out in Article VII., cover one or more periods which elapse between the cleaning of the fires, the same principle applies as that mentioned under the above heading (*a*); viz., the coal measurement begins with the first firing, after cleaning and burning down, and the measurement ends with the last firing, before cleaning and burning down at the close of the trial.

(*c*) *Coal Tests in General:* When not otherwise specially understood, a coal test of a combined engine and boiler plant is held to refer to the commercial test above noted, and the measurement of coal should conform thereto.

In connection with coal measurements, whatever the class of tests, it is important to ascertain the percentage of moisture in the coal, the weight of ashes and refuse, and, where possible, the approximate and ultimate analysis of the coal, following all the methods and details advocated in the latest report of the Boiler Test Committee of the Society. (See vol. xxi., p. 34.)

(*d*) *Other Fuels than Coal:* For all other solid fuels than coal the same directions in regard to measurement should be followed as those given for coal. If the boilers are run with oil or gas, the measurements relating to stopping and starting are much simplified, because the fuel is burned as fast as supplied, and there is no body of fuel constantly in the furnace, as in the case of using solid fuel. When oil is used, it should be weighed, and when gas is used, it should be measured in a calibrated gas meter or a gasometer.

XIII. INDICATED HORSE-POWER.—The indicated horse-power should be determined from the average mean effective pressure of diagrams taken at intervals of twenty minutes, and at more frequent intervals if the nature of the test makes this necessary, for each end of each cylinder. With variable loads, such as those of engines driving generators for electric railroad work, and of rubber-grinding and rolling-mill engines, the diagrams cannot be taken too often. In cases like the latter, one method of obtaining suitable averages is to take a series of diagrams on the same blank card without unhooking the driving cord, and apply the pencil at successive intervals of ten seconds until two minutes' time or more has elapsed, thereby obtaining a dozen or more indications in the time covered. This tends to insure the determination of a fair average for that period. In taking diagrams for variable loads, as indeed for any load, the pencil should be applied long enough to cover several successive revolutions, so that the variations produced by the action of the governor may be properly recorded. To determine whether the governor is subject to what is called "racing" or "hunting," a "variation diagram" should be obtained; that is, one in which the pencil is applied a sufficient time to cover a complete cycle of variations. When the governor is found to be working in this manner, the defect should be remedied before proceeding with the test.

It is seldom necessary, as far as average power measurements are concerned, to obtain diagrams at precisely the same instant at the two ends of the cylinder, or at the same instant on all the cylinders, when there are more than one. All that is required is to take the diagrams at regular intervals. Should the diagrams vary so much among themselves that the average may not be a fair one, it signifies that they should be taken more frequently, and not that special care should be employed to obtain the diagrams of each set at precisely the same time. When diagrams are taken during the time when the engine is working up to speed at the start, or when a study of valve setting and steam distribution is being made, they should be taken at as nearly the same time as practicable. In cases where the diagrams are to be taken simultaneously, the best plan is to have an operator stationed at each indicator. This is desirable, even where an electric or other device is employed to operate all the instruments at once; for unless there are enough operators, it is necessary to open the indicator cocks some time before taking the diagrams and run the risk of clogging the pistons and heating the high pressure springs above the ordinary working temperature.

The most satisfactory driving rig for indicating seems to be some form of well-made pantagraph, with driving cord of fine annealed wire leading to the indicator. The reducing motion, whatever it may be, and the connections to the indicator, should be so perfect as to produce diagrams of equal lengths when the same indicator is attached to either end of the cylinder, and produce a proportionate reduction of the motion of the piston at every point of the stroke, as proved by test.

With a perfect working pantagraph, or similar apparatus, the equality in the length of diagrams taken with the same indicator at the two ends is sufficient indication of the substantial reliability of the reduction when the point of cut-off on the diagram is not unusually short—say, not shorter than one-eighth. When the cut-off is unusually short, the error produced by imperfect reduction becomes a comparatively large item, and one which for accurate work should be allowed for. To test the accuracy of the reducing motion without making special preparations for a thorough examination, it is sufficient to make a comparison between the actual proportion of the stroke covered and the apparent proportion measured on the indicator, and see how they agree. This may be done on a large engine by making the comparison wherever it happens to stop, and repeating the comparison when it has stopped with the piston at some other point of the stroke. With an engine which can be turned over by hand, or where auxiliary power is provided for moving it, the comparison may be made at a number of equi-distant points in the stroke. To make the test properly, a diagram should be taken just before stopping, and this will serve as a reference for the measurements taken after stopping. The actual proportion of stroke covered is determined by measuring the distance which the crosshead has moved and comparing it with the whole length of the stroke, making sure that the slack has all been taken up by turning sufficient steam into the cylinder to bring a pressure to bear on the piston, but not sufficient to start the flywheel in motion. To obtain the apparent indication from the diagram, the indicator pencil is moved up and down with the finger so as to make a vertical mark on the diagram, and the distance of this mark from the beginning of the diagram compared to the whole length of the diagram is the proportion desired.

It is necessary, of course, to go through these operations without changing in any way the adjustment of the driving cord of the indicator, or any part of the mechanism that would alter the movements of the indicator.

The use of a three-way cock and a single indicator connected to the two ends of the cylinder is not advised, except in cases where it is impracticable to use an indicator close to each end. If a three-way cock is used, the error produced should be determined and allowed for.

The effect of the error produced by a three-way cock is usually to increase the area of the diagram. This is due to the tardiness of the indicator in responding to the changes of pressure. In an investigation made by one of the Committee, which was carried out both on short-stroke engines running at high speed and long-stroke engines running at comparatively slow speed, it was found that the increased area of the diagram, due to the sluggish action produced by the three-way cock, ranged from 3 to 7 per cent. as compared with an indicator with a short and direct pipe.

In the manipulation of the indicator it is important to keep the instrument in clean condition and preserve it in mechanically good order. Ordinary cylinder oil is the best material to use for lubricating the indicator piston for pressures above the atmosphere. It is better to have the piston fit the cylinder rather loosely—so as to get absolute freedom of motion--than to have a mathematically accurate fit. In the latter case, extreme care and frequent cleanings are required to obtain good diagrams. No diagrams should be accepted in which there is any appearance of want of freedom in the movement of the mechanism. A ragged or serrated line in the region of the expansion or compression lines is a sure indication that the piston or some part of the mechanism sticks; and when this state of things is revealed the indicator should not be trusted, but the cause should be ascertained and a suitable remedy applied. Entire absence of wire drawing of the steam line, and especially a sharp, square corner at the beginning of the steam line, should be looked upon with suspicion, however desirable and satisfactory these features might otherwise be. These are frequently produced by an indicator which is defective owing to want of freedom in the mechanism. An indicator which is free when subjected to a steady steam pressure, as it is under a test of the springs for calibration, should be able to produce the same horizontal line, or substantially the same, after pushing the pencil down with the finger, as that traced after pushing the pencil up and subsequently tapping it lightly. When the pencil is moved by the finger, first up and then down, the piston being subjected to pressure, the movement should appear smooth to the sense of feeling.

The point selected for attaching an indicator to the cylinder should never be the drip pipe or any point where the water of condensation will run into the instrument, if this can possibly be avoided. The admission of water with the steam may greatly distort the diagram. If it becomes necessary to place the indicator in such a position, as may happen when it is attached to the lower end of a vertical cylinder, the connection to the indicator must be short and direct, and in some cases it should be provided with a drip chamber arranged so as to collect the water or deflect it from entering the instrument.

In all cases the pipes leading to indicators should be as short and direct as possible.

To determine the average power developed in cases where the engine starts from rest during the progress of the trial, as in a commercial test of a plant where the engine runs only a portion of the twenty-four hours, a number of diagrams should be taken during the period of getting up speed and applying the working load, the corresponding speed for each set of diagrams being counted. The power shown by these diagrams for the proportionate time should be included in the average for the whole run, and the duration should be the time the throttle valve is open.

XIV. Testing Indicator Springs.—To make a perfectly satisfactory comparison of indicator springs with standards, the calibration should be made, if this were practical, under the same conditions as those pertaining to their ordinary use. Owing to the fact that the pressure of the steam in the indicator cylinder and the corresponding temperature are undergoing continual changes, it becomes almost impossible to compare the springs with any standard under such conditions. There must be a constant pressure during the time that the comparison is being made. Although the best that can be done is not altogether satisfactory, it seems that we must be content with it. To bring the conditions as nearly as possible to those of the working indicator, the steam should be admitted to the indicator as short a time as practicable for each of the pressures tried, and then the indicator cock should be closed and the steam exhausted therefrom before another pressure is tried. By this means the parts are heated and cooled somewhat the same as under the working conditions. We recommend, therefore, that for each required pressure the first step be to open and close the indicator cock a number of times in quick succession, then to quickly draw the line on the paper for the desired record, observing the gauge or other standard at the instant when the line is drawn. A corresponding atmospheric line is taken immediately after obtaining the line at the given pressure, so as to eliminate any difference in the temperature of the parts of the indicator. This appears to be a better method (although less readily carried on and requiring more care) than the one heretofore more commonly used, where the indicator cock is kept continually open, and the pressure is gradually rising or falling through the range of comparison.

The calibration should be made for at least five points, two of these being for the pressures corresponding as near as may be to the initial and back pressures, and three for intermediate points equally distant.

For pressures above the atmosphere, the proper standard recommended is the dead-weight testing apparatus, or a reliable mercury column, or an accurate steam gauge proved correct, or of known error, by either of these standards. For pressures below the atmosphere the best standard to use is a mercury column.

The correct scale of spring to be used for working out the mean effective pressure of the diagrams should be the average based on the calibration, and this may be ascertained in the manner pointed out below.

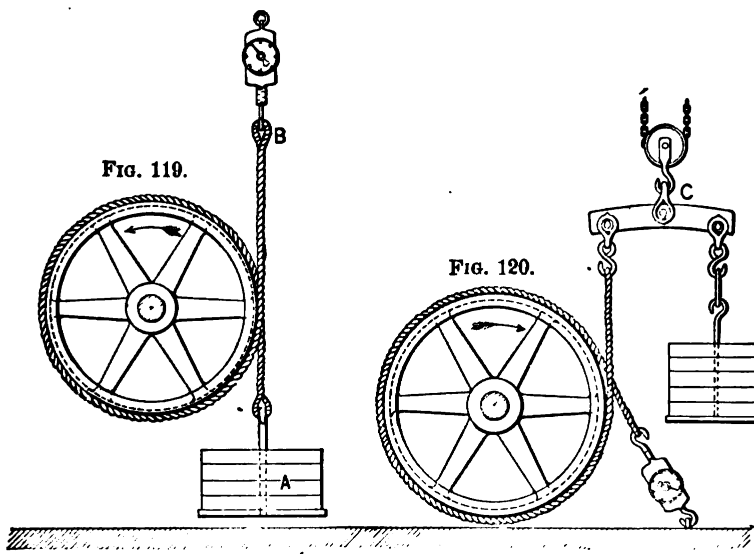
When the scale of the spring determined by calibration is found to vary from the nominal scale with substantial uniformity, it is usually sufficiently accurate to take the arithmetical mean of the scales found at the different pressures tried. When, however, the scale varies considerably at the different points, and absolute accuracy is desired, the method to be pursued is as follows: Select a sample diagram and divide it into a number of parts by means of lines parallel to the atmospheric line, the number of lines being equal to and corresponding with the number of points at which the calibration of the spring is made. Take the mean scale of the spring for each division, and multiply it by the area of the diagram enclosed between two contiguous lines. Add all the products together and divide by the area of the whole diagram; the result will be the average scale of the spring to be used. If the sample diagram selected is a fair representative of the entire set of diagrams taken during the test, this average scale can be applied to the whole. If not, a sufficient number of sample diagrams representing the various conditions can be selected, and the average scale determined by a similar method for each, and thereby the average for the whole run.

To make sure of substantial freedom of motion of the piston, and absence of undue friction, the tests relating to this matter in Section XIII. should be made for each of the pressures of calibration.

XV. BRAKE HORSE-POWER.—This term applies to the power delivered from the flywheel shaft of the engine. It is the power absorbed by a friction brake applied to the rim of the wheel, or to the shaft. A form of brake is preferred that is self-adjusting to a certain extent, so that it will, of itself, tend to maintain a constant resistance at the rim of the wheel. One of the simplest brakes for comparatively small engines, which may be made to embody this principle, consists of a cotton or hemp rope, or a number of ropes, encircling the wheel, arranged with weighing scales or other means for showing the strain. An ordinary band brake may also be constructed so as to embody the principle. The wheel should be provided with interior flanges for holding water used for keeping the rim cool.

FIG. 119.

FIG. 120.



A self-adjusting rope brake is illustrated in Fig. 119, where it will be seen that, if the friction at the rim of the wheel increases, it will lift the weight *A*, which action will diminish the tension in the end *B* of the rope, and thus prevent a further increase in the friction. The same device can be used for a band brake of the ordinary construction. Where space below the wheel is limited, a cross bar, *C*, supported by a chain tackle exactly at its centre point may be used as shown in Fig. 120, thereby causing the action of the weight on the brake to be upward. A safety stop should be used with either form, to prevent the weights being accidentally raised more than a certain amount.

The water-friction brake is specially adapted for high speeds and has the advantage of being self-cooling. The Alden brake is also self-cooling and is capable of fine adjustment.

A water-friction brake is shown in Fig. 121. It consists of two circular disks, *A* and *B*, attached to the shaft *C*, and revolving in a case, *E*, between fixed planes. The space between the disks and planes is supplied with running water, which enters at *D* and escapes at the cocks *F*, *G*, and *H*. The friction of the water against the surfaces constitutes a resistance which absorbs the desired power, and the heat generated within is carried away by the water itself. The water is thrown outward by centrifugal action and fills the outer portion of the case. The greater the depth of the ring of water, the greater the amount of power absorbed. By suitably adjusting the amount of water entering and leaving any desired power can be obtained. Water-friction brakes have been used successfully at speeds of over 20,000 revolutions per minute.

For description of the Alden brake, see *Transactions*, vol. xi., p. 958.

XVI. Quality of Steam.—When ordinary saturated steam is used, its quality should be obtained by the use of a throttling

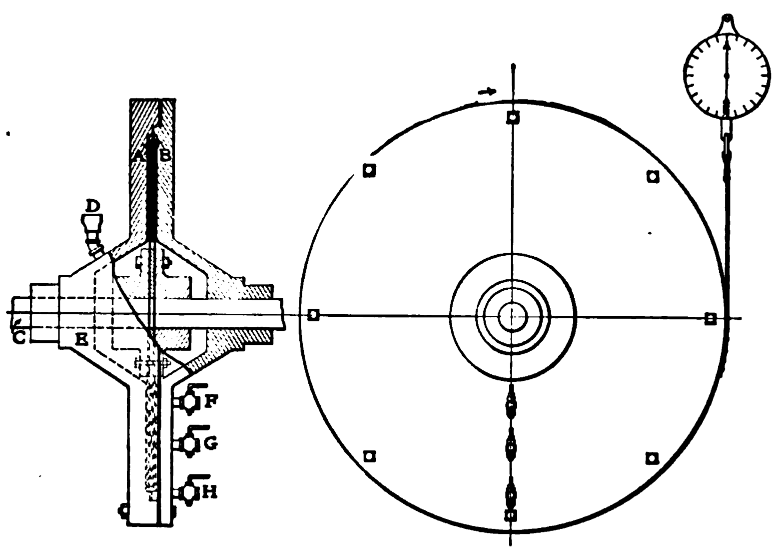


Fig. 121.

calorimeter attached to the main steam pipe near the throttle valve. When the steam is superheated, the amount of superheating should be found by the use of a thermometer placed in a thermometer-well filled with mercury, inserted in the pipe. The sampling pipe for the calorimeter should, if possible, be attached to a section of the main pipe having a vertical direction, with the steam preferably passing upward, and the sampling nozzle should be made of a half-inch pipe, having at least 20 one-eighth-inch holes in its perforated surface. The readings of the calorimeter should be corrected for radiation of the instrument, or they should be referred to a normal reading, as pointed out below. If the steam is superheated, the amount of superheating should be obtained by referring the reading of the thermometer to that of the same thermometer when the steam within the pipe is saturated, and not by taking the difference between the reading of the thermometer and the temperature of saturated steam at the observed pressure as given in a steam table.

If it is necessary to attach the calorimeter to a horizontal section of pipe, and it is important to determine the quantity of moisture accurately, a sampling nozzle should be used which has no perforations, and which passes through a stuffing box applied to the bottom of the pipe so that it can be adjusted up and down, and thereby draw a sample at different points ranging from the top to the bottom. By this means the character of the steam in the lower portion of the pipe, where it contains the most moisture, can be determined, and especially that at the very bottom, where there is usually more or less water being carried along the pipe. If, by a preliminary test, water is found at this point, we recommend that a drip pipe be attached a short distance in front of the calorimeter, the end of the drip being below the level of the bottom, and a sufficient quantity of steam be drawn off while the trial continues, to remove the water and cause the calorimeter to show dry steam at whatever height the sampling nozzle is adjusted. The quantity of steam and water thus drawn off should be determined by passing it under pressure through a separator, weighing the water after cooling it, and the steam after condensing. If the amount of water on the bottom of the pipe is so excessive that it cannot be removed by this means, or in cases where the main pipe is vertical, and the calorimeter shows that the percentage of moisture varies widely, sometimes exceeding 3 per cent., we recommend that a separator should be introduced before making a test, so as to free the steam of all moisture that it is possible to remove, the calorimeter being attached beyond the separator.

To determine the "normal reading" of the calorimeter, the instrument should be attached to a horizontal steam pipe in such a way that the nozzle projects upwards to near the top of the pipe, there being no perforations and the steam entering through the open end. The test should be made when the steam in the pipe is in a quiescent state, and when the steam pressure is constant. If the steam pressure falls during the time when the observations are being made, the test should be continued long enough to obtain the effect of an equivalent rise of pressure. When the normal reading has been obtained, the constant to be used in determining the percentage of moisture is the latent heat of the steam at the observed pressure divided by the specific heat of superheated steam at atmosphere pressure, which is forty-eight hundredths (0.48). To ascertain this percentage, divide the number of degrees of cooling by the constant, and multiply by 100.

To determine the quantity of steam used by the calorimeter in an instrument where the steam is passed through an orifice under a given pressure, it is usually accurate enough to calculate the quantity from the area of the orifice and the absolute pressure, using Rankine's well-known formula for the number of pounds which passes through per second; that is, absolute pressure in pounds per square inch divided by 70 and multiplied by the area of orifice in square inches. If it is desired to determine the quantity exactly, a steam hose may be attached to the outlet of the calorimeter, and carried to a barrel of water placed on a platform scale. The steam is condensed for a certain time and its weight determined, and thereby the quantity discharged per hour.

XVII. SPEED.—There are several reliable methods of ascertaining the speed, or the number of revolutions of the engine crank-shaft per minute. The simplest is the familiar method of counting the number of turns for a period of one minute with the eye fixed on the second hand of a timepiece. Another is the use of a counter held for a minute or a number of minutes against the end of the main shaft. Another is the use of a reliable calibrated tachometer held likewise against the end of the shaft. The most reliable method, and the one we recommend, is the use of a continuous recording engine register or counter, taking the total reading each time that the general test data are recorded, and computing the revolutions per minute corresponding to the difference in the readings of the instrument. When the speed is above 250 revolutions per minute, it is almost impossible to make a satisfactory counting of the revolutions without the use of some form of mechanical counter.

The determination of variation of speed during a single revolution, or the effect of the fluctuation due to sudden changes of the load, is also desirable, especially in engines driving electric generators used for lighting purposes. There is at present no recognized standard method of making such determinations, and if such are desired, the method employed may be devised by the person making the test, and described in detail in the report.

One method suggested for determining the instantaneous variation of speed which accompanies a change of load, is as follows: A screen containing a narrow slot is placed on the end of a bar and vibrated by means of electricity. A corresponding slot in a stationary screen is placed parallel and nearly touching the vibrating screen, and the two screens are placed a short distance from the flywheel of the engine in such a position that the observer can look through the two slots in the direction of the spokes of the wheel. The vibrations are adjusted so as to conform to the frequency with which the spokes of the wheel pass the slots. When this is done the observer viewing the wheel through the slots sees what appears to be a stationary flywheel. When a change in the velocity of the flywheel occurs, the wheel appears to revolve either backward or forward according to the direction of the change. By careful observations of the amount of this motion, the angular change of velocity during any given time is revealed.

Experiments that have been made with a device of this kind show that the instantaneous gain of velocity, upon suddenly removing all the load from an engine, amounted to from one-sixth to one-quarter of a revolution of the wheel.

XVIII. Recording the Data.—Take note of every event connected with the progress of the trial whether it seems at the time to be important or unimportant. Record the time of every event, and time of taking every weight, and every observation. Observe the pressures, temperatures, water heights, speeds, etc., every twenty or thirty minutes when the conditions are practically uniform, and at much more frequent intervals if the conditions vary. Observations which concern the feed-water measurement should be made with special care at the expiration of each hour of the trial, so as to divide the tests into hourly periods and show the uniformity of the conditions and results as the test goes forward. Where the water discharged from a surface condenser is weighed it may be advisable to divide the test by this means into periods of less than one hour.

The data and observations of the test should be kept on properly prepared blanks or in note-books containing columns suitably arranged for a clear record. As different observers have their own individual ideas as to how such records should be kept, no special form of log sheet is given as a necessary part of the code.

XIX. Uniformity of Conditions.—In a test, having for an object the determination of the maximum economy obtainable from an engine, or where it is desired to ascertain with special accuracy the effect of predetermined conditions of operation, it is important that all the conditions under which the engine is operated should be maintained uniformly constant. This requirement applies especially to the pressure, the speed, the load, the rate of feeding the various supplies of water, the height of water in the gauge glasses, and the depth of water in the feed-water reservoir.

XX. Analysis of Indicator Diagrams.—(a) *Steam Accounted for by the Indicator.* The simplest method of computing the steam accounted for by the indicator is the use of the formula,

$$M = \frac{13750}{\text{M.E.P.}} [(C + E) \times Wc - (H + E) \times Wh],$$

which gives the weight in pounds per indicated horse-power per hour. In this formula the symbol "M.E.P." refers to the mean effective pressure. In multiple-expansion engines, this is the combined mean effective pressure referred to the cylinder in question. The symbol C refers to the proportion of the stroke completed at points on the expansion line of the diagram near the actual cut-off or release; the symbol H to the proportion of

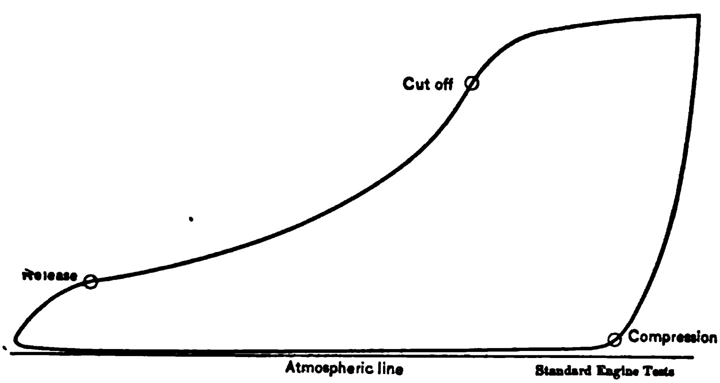


FIG. 122.—SHOWING POINTS WHERE "STEAM ACCOUNTED FOR BY INDICATOR" IS COMPUTED.

compression; and the symbol E to the proportion of clearance; all of which are determined from the indicator diagram. The symbol Wc refers to the weight of one cubic foot of steam at the cut-off or release pressure; and the symbol Wh, to the weight of one cubic foot of steam at the compression pressure; these weights being taken from steam tables of recognized accuracy. The points near the cut-off and release on the expansion line, and the point on the compression line, are located as shown on the sample diagram Fig. 122. They are the points in the case of the expansion and compression lines of the diagram which mark the complete closure of the valve. The point near the cut off, for example, lies where the curve of expansion begins after the rounding of the diagram due to the wire-drawing which occurs while the valve is closing. This cut-off may be located by finding the point where the curve is tangent to a hyperbolic curve.

Should the point in the compression curve be at the same height as the point in the expansion curve, then $Wc = Wh$, and the formula becomes,

$$\frac{13750}{\text{M.E.P.}} \times (C - H) \times Wc,$$

in which $(C - H)$ represents the distance between the two points divided by the length of the diagram.

When the load and all other conditions are substantially uniform, it is unnecessary to work up the steam accounted for by the indicator from all the diagrams taken. Five or more sample diagrams may be selected and the computations based on the samples instead of on the whole.

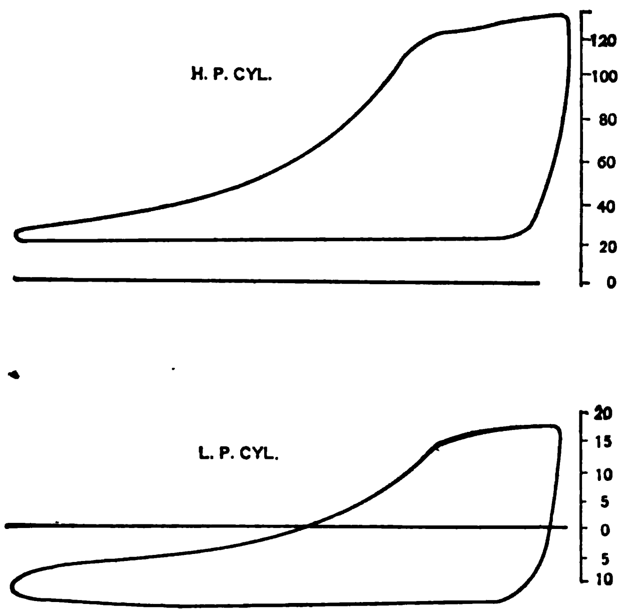
The "combined" mean effective pressure in a multiple-expansion engine is determined as follows: Take, for example, a compound engine. The combined mean effective pressure for the high pressure cylinder is made up of two items—the first being the mean effective pressure of the high-pressure cylinder, and the second being the mean effective pressure of the low-pressure cylinder multiplied by the ratio which the volume of piston displacement of the low-pressure cylinder bears to that of the high-pressure cylinder. The sum of these two items gives the combined mean effective pressure for the high-pressure cylinder. Likewise, the combined mean effective pressure for the low-pressure cylinder is made up of two items, one of which is the mean effective pressure of the low-pressure cylinder, and the other the mean effective pressure of the high-pressure cylinder divided by the ratio mentioned. The sum of these two items gives the combined mean effective pressure for the low-pressure cylinder.

In working out the "steam accounted for," in a case where the mean effective pressure is widely different at the two ends of the cylinder. that part of the formula exclusive of the mean effective pressure should be computed for each end separately. The two results are then added together and divided by the sum of the two mean effective pressures, and this gives the desired average.

(b) *Sample Indicator Diagrams:* In order that the report of a test may afford complete information regarding the conditions of the test, sample indicator diagrams should be selected from those taken and copies appended to the tables of results. In cases where the engine is of the multiple-expansion type these sample diagrams may also be arranged in the form of a "combined" diagram.

The "Combined Diagram" is a hypothetical figure, which in its essential features represents an indicator diagram which would be obtained if the whole process of admission, expansion and exhaust occurred in one cylinder, viz., the low-pressure cylinder. It is a diagram from which the pressure of the steam at any point in the stroke of either cylinder, and the volume of that steam can be measured from one diagram, in the same manner that it can be measured in the case of a single cylinder engine from the actual indicator diagram.

The general method of laying out a combined diagram, is shown in



Standard Engine Tests

FIG. 123.—ACTUAL DIAGRAM. RECEIVER ENGINE.

the appended cuts (Figs. 123 to 126), the first of which refer to a Corliss compound engine (receiver engine), in which the ratio of volumes of the two cylinders is as 3.72 to 1, and the clearance of the high-pressure cylinder is 4 per cent., and of the low-pressure cylinder, 4.8 per cent.; and the second, to a Westinghouse compound engine (Woolf Engine), in which the ratio of volumes is as 2.72 to 1, and the clearance, 33 per cent. and 9 per cent. respectively. These diagrams are so clearly drawn that they will doubtless be readily understood without further description.

The principle to be followed in laying out combined diagrams when the engine is of more complicated character than the one referred to here, is, so far as possible, to show the volume and pressure of the steam at any point in either cylinder, so as to measure them directly from the combined diagram.

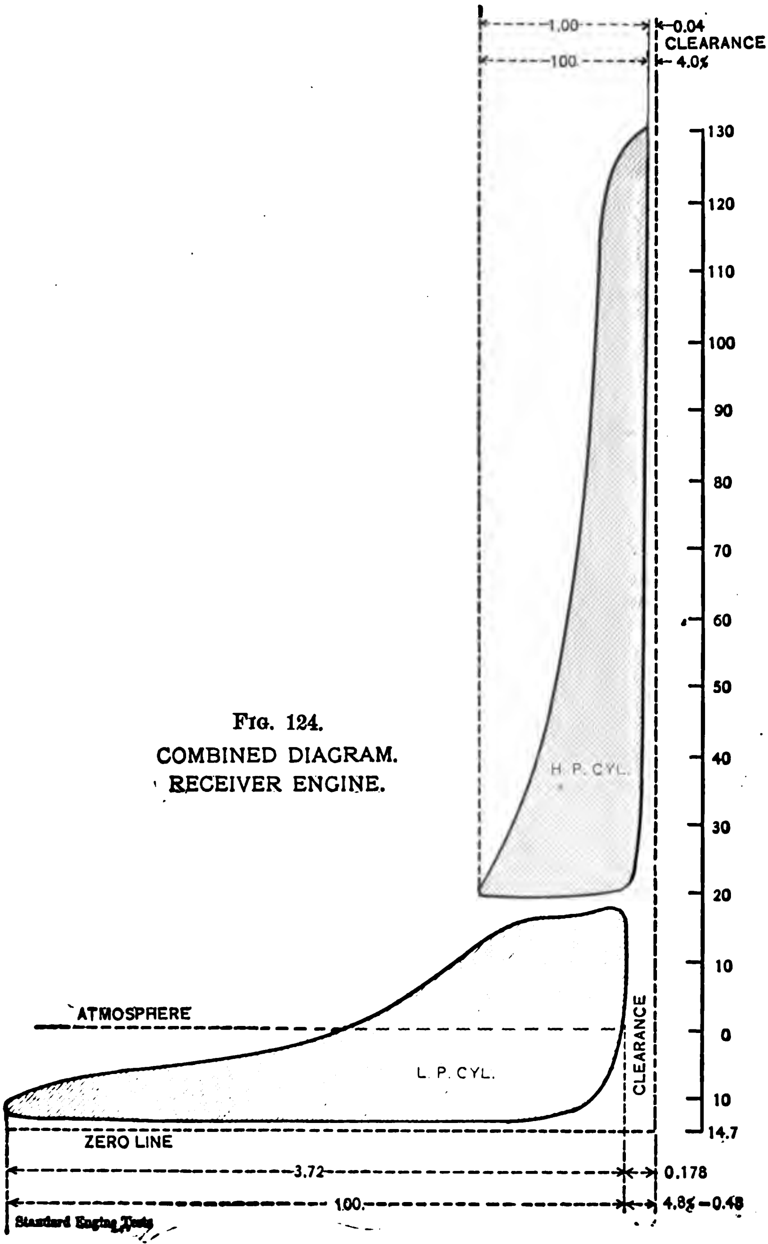


FIG. 124.
COMBINED DIAGRAM.
RECEIVER ENGINE.

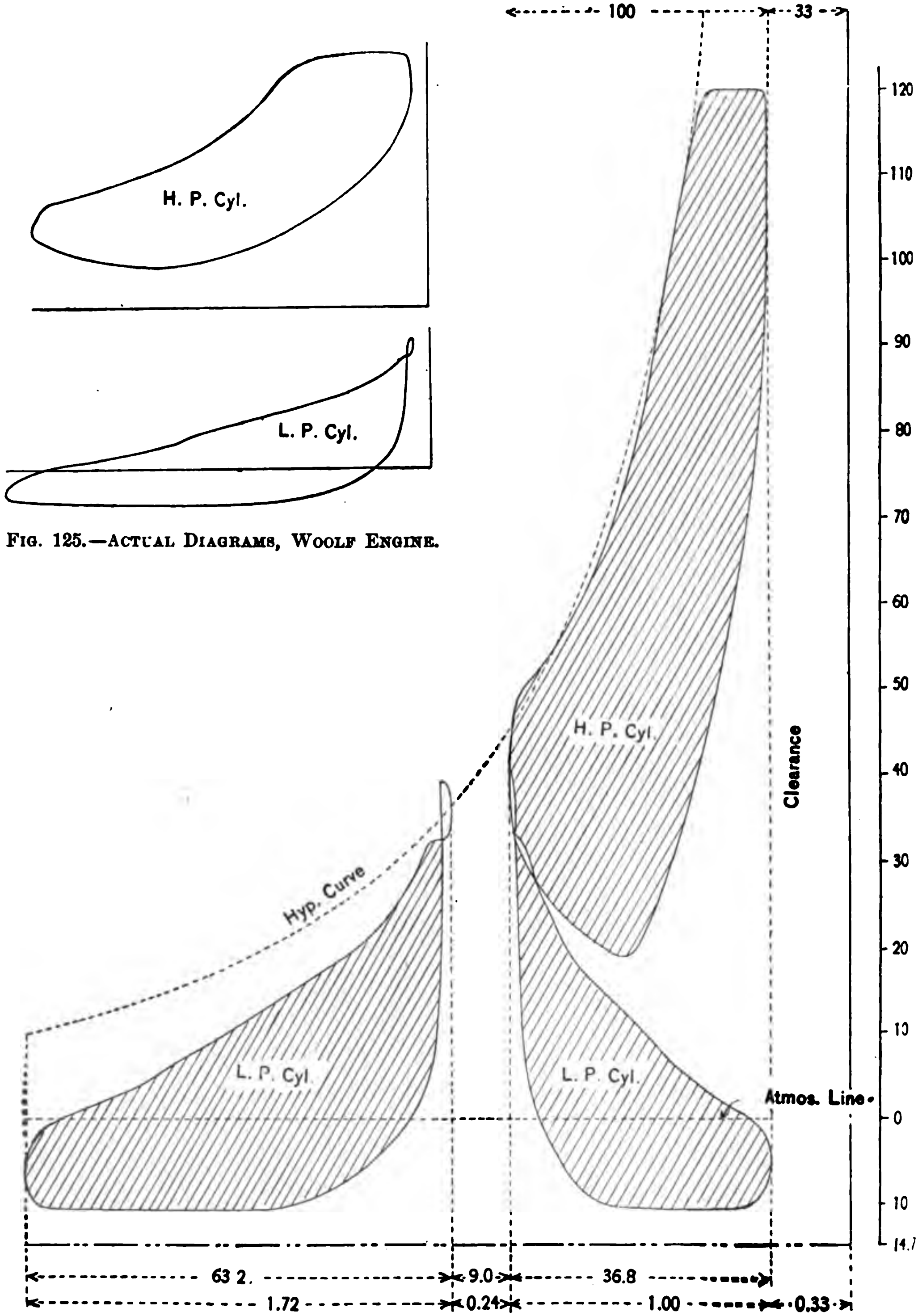


FIG. 125.—ACTUAL DIAGRAMS, WOOLF ENGINE.

FIG. 126.—COMBINED DIAGRAM, WOOLF ENGINE.

(c) *The Point of Cut-off:* The term "cut-off" as applied to steam engines, although somewhat indefinite, is usually considered to be at an earlier point in the stroke than the beginning

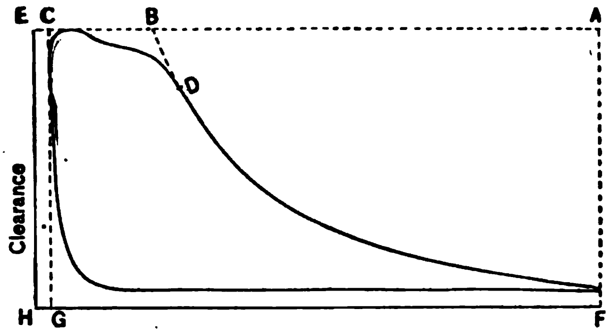


FIG. 127.—FOUR-VALVE ENGINE, SLOW SPEED.
COMMERCIAL CUT-OFF $= \frac{BC}{AC}$.

of the real expansion line. That the cut-off point may be defined in exact terms for commercial purposes, as used in steam-engine specifications and contracts, the Committee recommends that, unless otherwise specified, the *commercial cut-off*, which seems

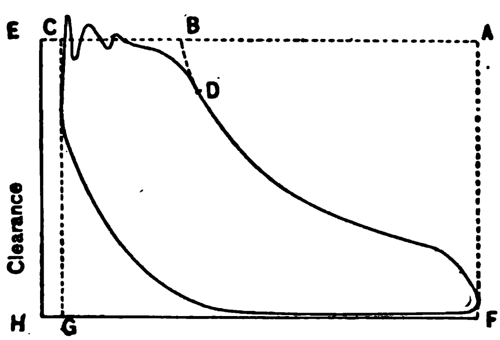


FIG. 128.—SINGLE-VALVE ENGINE, HIGH SPEED.
COMMERCIAL CUT-OFF $= \frac{BC}{AC}$.

to be an appropriate expression for this term, be ascertained as follows: Through a point showing the maximum pressure during admission, draw a line parallel to the atmospheric line. Through the point on the expansion line near the actual cut-off, referred to in Section XX. (a), draw a hyperbolic curve. The point where these two lines intersect is to be considered the *commercial cut-off* point. The percentage is then found by dividing the length of the diagram measured to this point, by the total length of the diagram, and multiplying the result by 100.

The principle involved in locating the commercial cut-off is shown in Figs. 127 and 128, the first of which represents a diagram from a slow-speed Corliss engine, and the second a diagram from a single valve high-speed engine. In the latter case where, owing to the fling of the pencil, the steam line vibrates, the maximum pressure is found by taking a mean of the vibrations at the highest point.

The *commercial cut-off*, as thus determined, is situated at an earlier point of the stroke than the actual cut-off referred to in computing the "steam accounted for" by the indicator in Section XX. (a).

(d) *Ratio of Expansion:* The ratio of expansion for a simple engine is determined by dividing the volume corresponding to the piston displacement, including clearance, by the volume of the steam at the commercial cut-off, including clearance.

In a multiple-expansion engine it is determined by dividing the net volume of the steam indicated by the low pressure diagram at the end of the expansion line, assumed to be continued to the end of the stroke, by the net volume of the steam at the maximum pressure during admission to the high pressure cylinder.

For example, in a simple engine, referring to Figs. 127 and 128, the ratio of expansion is the entire distance HF including clearance, divided by the distance EB including clearance; that is $\frac{HF}{EB}$.

For a compound engine, referring to the combined diagram Fig. 129, the ratio of expansion is the distance CD divided by the distance AB. In which E and F are points on the compression and expansion lines respectively of the high pressure diagram, the latter being near the point of cut-off; and H and G, points on the compression and expansion lines of the low pressure diagram, the latter being near the point of release, and the curves EA, FB, HC, and GD being hyperbolic. If it is desired to determine the ratio without laying out the combined diagram it can be done by drawing on the original diagrams the hyperbolic curves referred to above, and multiplying the ratio of volumes of the cylinders, first by the ratio of the length of the high pressure diagram to the distance AB and then by the ratio of the distance CD to the length of the low pressure diagram.

(e) *Diagram Factor:* The diagram factor is the proportion borne by the actual mean effective pressure measured from the indicator diagram to that of a diagram in which the various operations of admission, expansion, release and compression are carried on under assumed conditions. The factor recommended

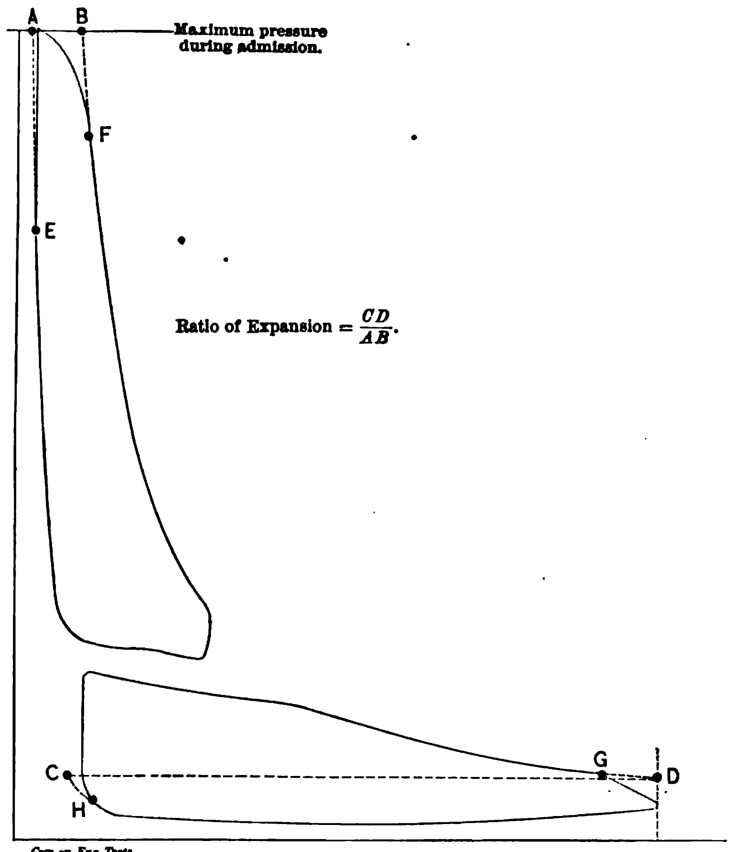


FIG. 129.

refers to an ideal diagram which represents the maximum power obtainable from the steam accounted for by the indicator diagrams at the point of cut-off, assuming first that the engine has no clearance; second, that there are no losses through wire-drawing the steam either during the admission or the release; third, that the expansion line is a hyperbolic curve; and fourth, that the initial pressure is that of the boiler and the back pressure that of the atmosphere for a non-condensing engine, and of the condenser for a condensing engine.

The diagram factor is useful for comparing the steam distribution losses in different engines, and is of special use to the engine designer, for by multiplying the mean effective pressure obtained from the assumed theoretical diagrams by it he will obtain the actual mean effective pressure that should be developed in an engine of the type considered. The expansion and compression curves are taken as hyperbolas, because such curves are ordinarily used by engine builders in their work, and a diagram based on such curves will be more useful to them than one where the curves are constructed according to a more exact law.

In cases where there is a considerable loss of pressure between the boiler and the engine, as where steam is transmitted from a central plant to a number of consumers, the pressure of the steam in the supply main should be used in place of the boiler pressure in constructing the diagrams.

The method of determining the diagram factor is best shown by referring to Figs. 130 to 133, which apply to a simple non-condensing engine, a simple condensing engine, and a compound condensing engine.

In Fig. 130 *RS* represents the volume of steam at boiler pressure admitted to the cylinder, *PR* and *OS* being hyperbolic curves drawn through the compression and cut-off points respectively. In Fig. 131 the factor is the proportion borne by the area of the actual diagram to that of the diagram *CNHSK*. In Fig. 132 the factor is the proportion borne to the area of the diagram *CNHSK*. In Fig. 133 the factor is the proportion borne by the area of the two combined diagrams to the area *CNHSK*. In Fig. 131, where the diagram is the same as in Fig. 130, the distance *CN* is laid off equal to *RS* shown in Fig. 130, and the curve *NH* is a hyperbola referred to the zero lines *CM* and *MJ*. In Fig. 132 the distance *CN* is found in a similar way. In Fig. 133 the distance *CN* for the high-pressure cylinder is found in the same manner as in the case of a simple engine. The mean effective pressure of the ideal diagram can readily be obtained from the formula

$$\frac{P}{R}(1 + \text{Hyp. Log. R.}) - p \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where P is the absolute pressure of the steam in the boiler, R the ratio $\frac{MJ}{CN}$, and p the pressure of the atmosphere or in the condenser.

XXI. Standards of Economy and Efficiency.—The hourly consumption of heat, determined by employing the actual tem-

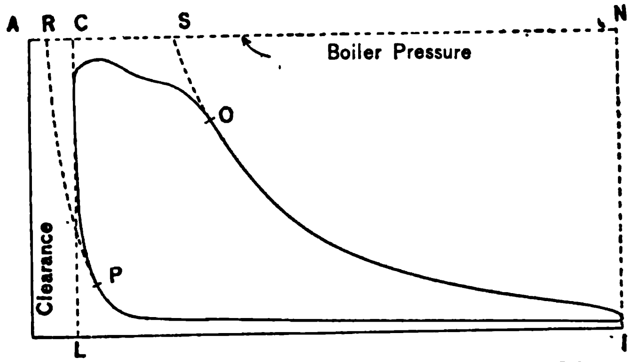


FIG. 130.—NET VOLUME OF STEAM ADMITTED = *RS*.

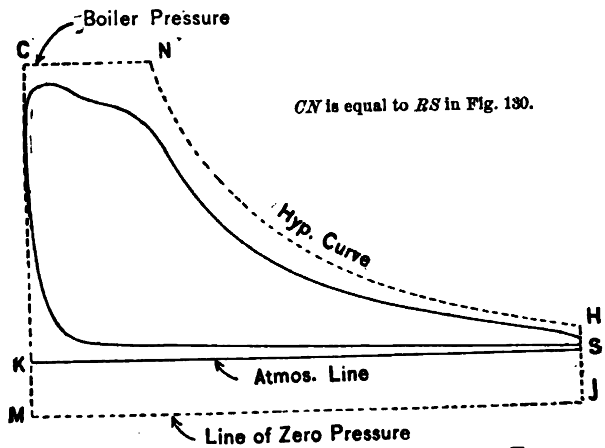


FIG. 131.—DIAGRAM FACTOR, NON-CONDENSING ENGINE.

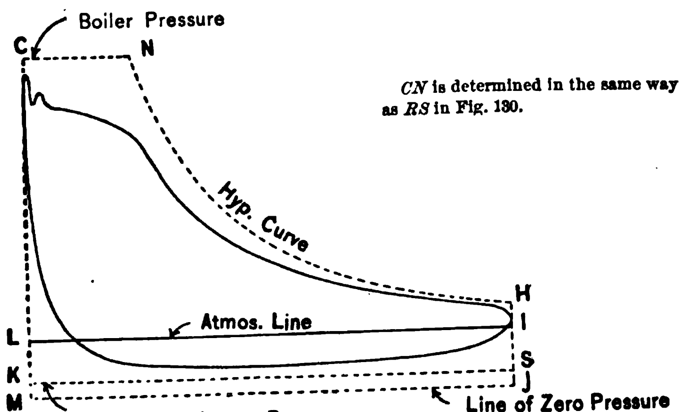


FIG. 132.—DIAGRAM FACTOR, CONDENSING ENGINE.

NC is determined for the high-pressure diagram in the same way as RS in Fig. 130.

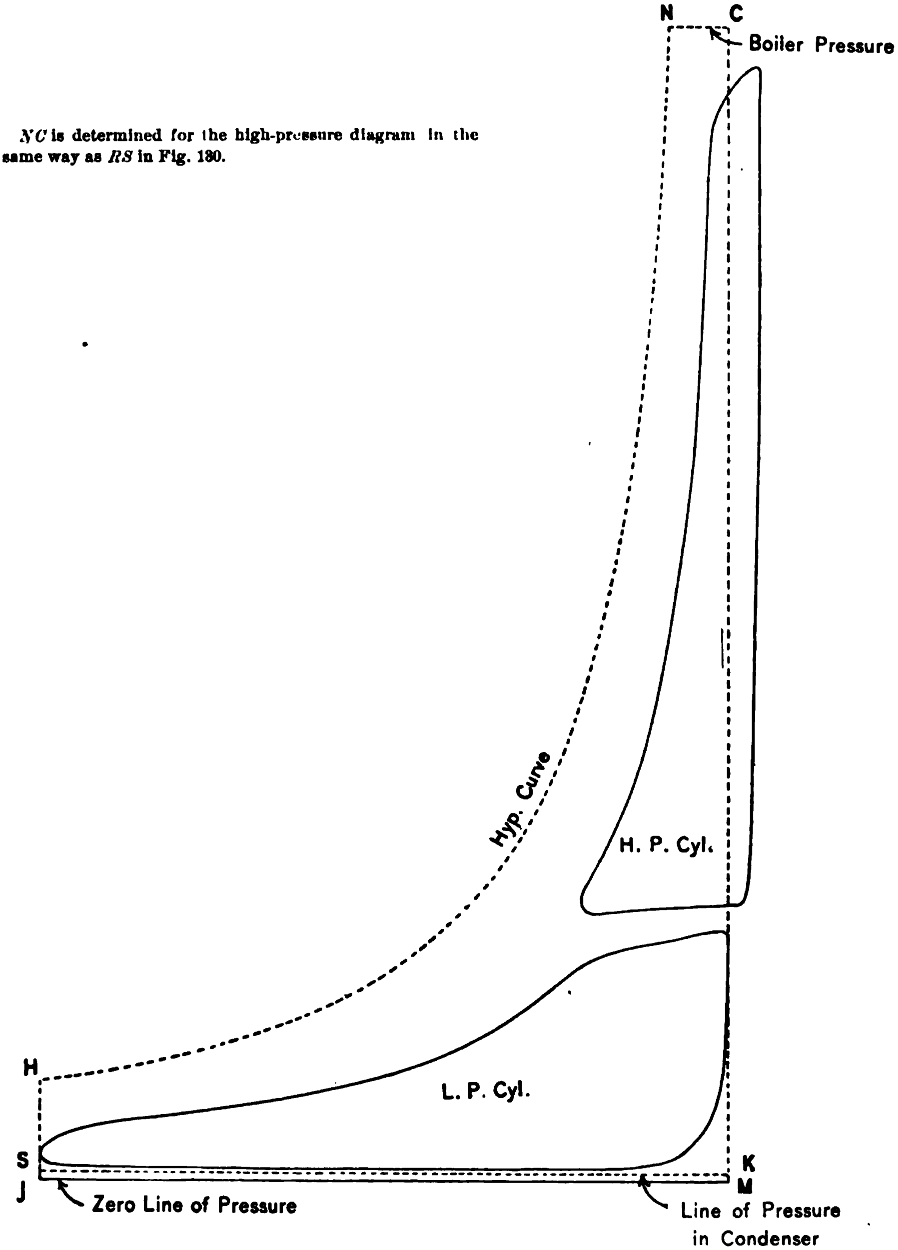


FIG. 133.—DIAGRAM FACTOR, COMPOUND ENGINE.

perature of the feed water to the boiler, as pointed out in Article IX. of the Code, divided by the indicated and brake horse-power, that is, the number of heat units consumed per indicated and per brake horse-power per hour, are the standards of engine efficiency recommended by the Committee. The consumption *per hour* is chosen rather than the consumption per minute, so as to conform with the designation of time applied to the more familiar units of coal and water measurement, which have heretofore been used. The British standard, where the temperature of the feed water is taken as that corresponding to the temperature of the back-pressure steam, allowance being made for any drips from jackets or reheaters, is also included in the tables.

It is useful in this connection to express the efficiency in its more scientific form, or what is called the "thermal efficiency ratio." The thermal efficiency ratio is the proportion which the heat equivalent of the power developed bears to the total amount of heat actually consumed, as determined by test. The heat converted into work represented by one horse-power is 1,980,000 foot-pounds per hour, and this divided by 778 equals 2,545 British thermal units. Consequently, the thermal efficiency ratio is expressed by the fraction

$$\frac{2{,}545}{\text{B. T. U. per H.-P. per hour.}}$$

MEMORANDA REGARDING THE BRITISH STANDARD.—The principal objection which the Committee has to the use of the British standard of engine economy for the leading place, is as follows :

The practical utility of an engine depends almost wholly upon the fact that it is used for some form of industrial work, and, in combination with a boiler and various appurtenances, it is a part of a complete power plant. Were it not for the unreliable character of coal and other fuels, the proper standard of economy for such an engine, with a boiler of given efficiency, would be the fuel consumed, because fuel is, in reality, the source of the power, and this is the most important thing to be supplied in operating the engine. The use of a standard of heat units in place of fuel, meets the objectionable characteristics of coal due to its heat variability, and in doing this, it makes no change in the conditions under which the standard should be employed. These are the actual conditions of use, and not the ideal conditions. The British method furnishes a means of determining and stating the ideal performance of an engine working under assumed conditions. It does not give the performance of the entire engine plant under the actual conditions as affected by the efficiency of the heaters and auxiliaries, and the performance under such conditions is usually of the greatest importance.

The advantages in favor of the British standard are as follows:

1. It expresses the economy of the engine as an independent machine, unaffected by the failings of the feed-water heater or condenser.

2. In this form, it is useful for expressing the economy of an engine in the testing shop of an engine builder, or in the mechanical laboratory of a college, where it forms no part of a power plant.

3. A comparison of the British standard with the economy of an ideal engine working between the same limits of temperature reveals those losses going on which are due to the engine alone, and this furnishes information not otherwise obtained.

The arrangement of the various forms used in stating the efficiency, as proposed by the Committee, gives due weight to both of these standards, placing the one in the lead which is regarded as the most important.

XXII. HEAT ANALYSIS.—For certain scientific investigations, it is useful to make a heat analysis of the diagram, to show the interchange of heat from steam to cylinder walls, etc., which is going on within the cylinder. This is unnecessary for commercial tests.

Reference may be made to the standard text-books on thermodynamics for detailed information regarding the methods to be pursued and the formulæ to be used in working out the heat analysis. The principles involved may be briefly summarized as follows: A certain amount of heat is supplied to the engine in a given time, and this is represented by the number of pounds of steam supplied multiplied by the total heat of one pound of the same. A part of this heat is used in the jacket, if such be employed, and the balance passes through the cylinder. That which enters the jacket is lost partly by radiation from the outside surface, and the remaining portion enters the walls of the cylinder and is taken up by the steam within it. The operations going on within the cylinder consist, first, of the transfer of a portion of the entering heat into a small portion of the thickness of the walls of the cylinder, heating them to the temperature of the entering steam. This transfer of heat is most active during the period of steam admission and up to the point of cut-off. After the cut-off, the transfer continues until the lower pressure due to expansion reaches such a point that the temperature of the steam is below that of the interior surfaces last uncovered. Then the interchange of heat is reversed, and the metal gives up heat to the steam and causes what is known as re-evaporation of the particles of water on the surface of the cast-iron walls and piston. The giving up of heat from the small thickness of the surfaces which were heated during admission to the temperature of the entering steam begins after cut-off takes place, or, to be more explicit, after the pressure begins to fall, and continues during the entire stroke. Heat is also given off from the metal of the cylinder to the steam, due to the higher temperature of the jacket, if such be used, and this occurs throughout the whole of the stroke, assuming what is usually true that the pressure of steam in the jacket is greater than that in the cylinder.

There is another action going on in the cylinder and that is the loss of heat due to the performance of work. There is also a loss of heat due to radiation from those portions of the cylinder not protected by the jacket. The quantity of heat remaining after the steam has been subjected to these various complicated actions is that which passes out with the steam through the exhaust valve and is thereby "rejected," as it is termed, to the condenser or to the atmosphere. The heat analysis determines the amount of heat which is used and transferred in these various actions during the time in question, and the various percentages which these amounts bear to the total quantity of heat supplied.

XXIII. Temperature-Entropy Diagram.—The study of the heat analysis is facilitated by the use of the temperature-entropy diagram in which areas represent quantities of heat, the coördinates being the absolute temperature and entropy. Such a diagram is shown in Fig. 134.

When the quantities given in the steam tables are plotted, two curves, AA and BB, are obtained which may be termed the water line and the steam line, AA being the logarithmic curve if the specific heat of the water is taken as constant. The diagram refers to a unit weight of the agent, and the heat necessary to raise a pound of water from the temperature ma to the temperature pa' and evaporate it at that temperature is represented by the area $aa'b'qm$. If the steam be now expanded adiabatically the temperature will fall to qs and x per cent. $= \frac{as}{ab}$ will remain as steam, the rest being liquefied. If the steam is now rejected, it carries away with it the heat $sqma$, the work area being $a'b'sa$, from which must be deducted the work w (expressed in heat units) to pump a pound of water into the boiler. The efficiency of this cycle is evidently

$$\frac{h + L_1 - xL_2 - w}{h + L_1}$$

in which

$$x = \frac{ar + a'b'}{ab} = \frac{\log_e \frac{T_1}{T_2} + \frac{L_1}{T_1}}{\frac{L_2}{T_2}}.$$

By the action of the walls a portion of the steam is liquefied prior to the expansion, which therefore begins at c, and since the cooling action of the walls continues, the expansion line falls off to ef, from which point a reverse action takes place, and the expansion line bends over to g. Finally, since the release takes place before the condenser temperature is reached, the heat rejection starts at g, following a line of equal volume until the exhaust port temperature is reached at j. If heat is added during expansion enough to keep the steam theoretically saturated, as, for example, by a water jacket, such additional heat is represented by the area $b'bnq$, and the additional work obtained by the triangle $b'bs$. If the steam is superheated sufficiently to give by expansion theoretically dry steam at the end, such additional heat is represented by the area $b'vnq$ and the additional work by $b'vbs$. Neither of these extra amounts of work are realized in practice, and it is evident from the diagram that the heat thus applied is in both cases less efficient than in the principal cycle. Nevertheless the action in each case

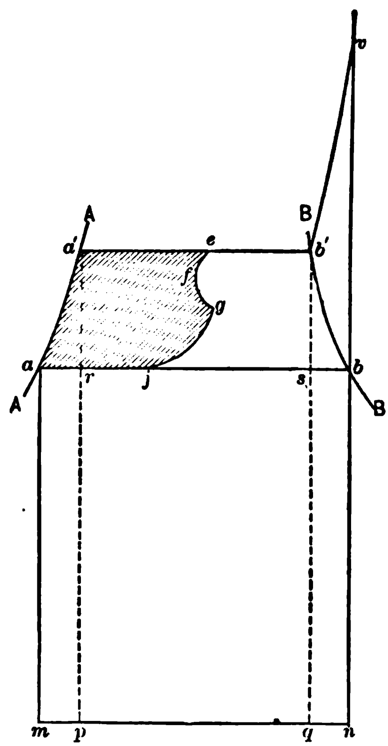


FIG. 134.—TEMPERATURE-ENTROPY DIAGRAM.

is to bring the point e nearer the point b', and to effect a notable net economy.

The Carnot cycle would be obtained if in the Rankine cycle the rejection of heat were stopped at r, and the temperature of the mixture raised to a' by compression This cannot be practically accomplished, but a system of feed-water heaters has been suggested and exemplified in the Nordberg engine, which is theoretically a close equivalent to it. Where steam is expanded in say three cylinders, the feed water may be successively heated from the receiver intermediate between each pair, the effect of which is illustrated in Fig. 135. The expansion line follows the heavy line, being carried over to y by the first feed water heater and to y' by the second feed-water heater. With an infinite number of such feed-water heaters, the line yy' would be parallel to aa', and the cycle equivalent to that of Carnot.

XXIV. Ratio of Economy of an Engine to that of an Ideal Engine.—The ideal engine recommended for obtaining this ratio is that which was adopted by the Committee appointed by the Civil Engineers, of London, to consider and report a standard thermal efficiency for steam engines. This engine is one which follows the Rankine cycle, where steam at a constant pressure is admitted into the cylinder with no clearance, and after the point

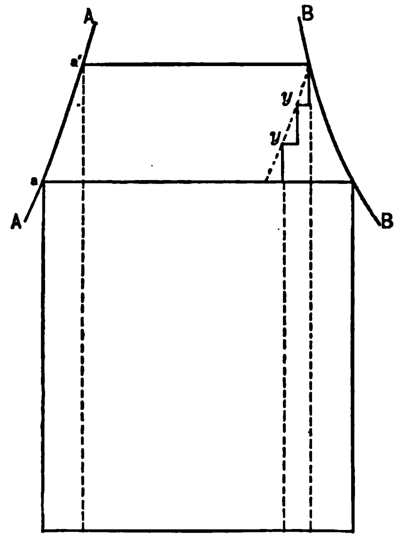


Fig. 135.—Temperature-Entropy Diagram.

of cut-off, is expanded adiabatically to the back pressure. In obtaining the economy of this engine the feed water is assumed to be returned to the boiler at the exhaust temperature. Such a cycle is preferable to the Carnot for the purpose at hand, because the Carnot cycle is theoretically impossible for an engine using superheated steam produced at a constant pressure, and the gain in efficiency for superheated steam corresponding to the Carnot efficiency will be much greater than that possible for the actual cycle.

The ratio of the economy of an engine to that of the ideal engine is obtained by dividing the heat consumption per indicated horse-power per minute for the ideal engine by that of the actual engine.

The economy of the ideal engine recommended can be readily obtained from the chart given in Fig. 136, which has been copied from the report already mentioned of the Committee appointed by the Civil Engineers, of London.

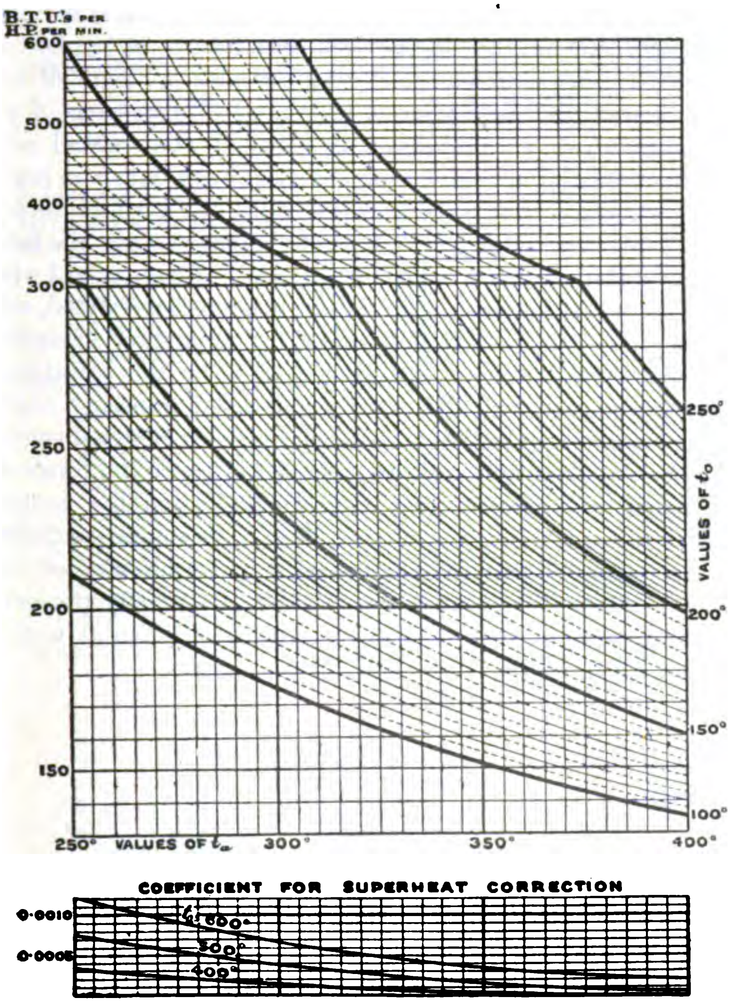
In Fig. 136, t_a represents the temperature of saturated steam at the boiler pressure in degrees Fahr.; t_{as} that of the steam furnished to the engine should there be superheating; t_e that of the exhaust. The British thermal units consumed per minute per indicated horse-power by the ideal engine can be read off directly from the curves given in the upper portion of the diagram; thus, if the temperature of the exhaust (t_e) is 212 degrees Fahr., and the temperature of the steam at boiler pressure 350 degrees Fahr., the heat consumption is 265 British thermal units per indicated horse-power per minute. If the steam is superheated, the figure obtained as just described is corrected by employing the factor obtained from the lower part of the diagram. Opposite the temperature of saturation corresponding to the pressure in the boiler, and on the curve corresponding to the temperature of superheated steam (t_{as}) is found a coefficient. This coefficient multiplied by the exhaust temperature, and by the heat consumption per minute obtained should there be no superheating, gives the deduction to be made on account of the superheating. Thus, if the temperature of the superheated steam is 500 degrees Fahr. in the case already considered for saturated steam, we find opposite 350 degrees for t_a, and on the curve for $t_{as} = 500$ degrees the coefficient 0.00015. This gives the correction $0.00015 \times 212 \times 265 = 8.5$ British thermal units, and the heat consumption of the engine when furnished with superheated steam will be $265 - 8.5 = 256.5$ British thermal units per indicated horse-power per minute.

XXV. MISCELLANEOUS.—In the case of tests of combined engines and boiler plants, where the full data of the boiler performance is to be determined, reference should be made to the directions given by the Boiler Test Committee of the Society, Code of 1899. (See Vol. XXI., p. 34.)

In tests made for scientific research, and in those made on special forms of engines, the line of procedure must be varied according to the special objects in view, and it has been deemed unnecessary to go into particulars applying to such tests.

In testing steam pumping engines and locomotives in accordance with the standard methods of conducting such tests, recommended by the committees of the Society, reference should

FIG. 136.—CURVES SHOWING BRITISH THERMAL UNITS EXPENDED PER MINUTE PER I. H. P. BY THE IDEAL STEAM ENGINE FORMING PART OF THE RANKINE CYCLE. (From the Minutes of Proceedings of the Civil Engineers of London.)



Temperatures are expressed in degrees Fahrenheit.

The upper and lower portions of the upper diagram are to different scales; this is in order that the lower and more important part may be read more easily, and accounts for the cusps in the curves.

be made to the reports of those committees in the *Transactions*, Volume XII., p. 530, and in Volume XIV., p. 1312.

XXVI. Report of Test.—The data and results of the test should be reported in the manner and in the order outlined in one of the following tables, the first of which gives, it is hoped, a complete summary of all the data and results as applied not only to the standard heat-unit test, but also to tests of combined engine and boiler for determining all questions of performance, whatever the class of service; the second refers to a short form of report giving the necessary data and results for the standard heat test; and the third to a short form of report for a feed-water test. It is the intention that the tables should be full enough to apply to any type of engine, but where not so, or where special data and results are determined, additional results may be inserted under the appropriate headings. Although these forms are arranged so as to be used for expressing the principal data and results of tests of pumping engines and locomotives, as well as for all other classes of steam engines, it is not the intention that they shall supplant the forms recommended by the committees on Duty Trials and Locomotives, in cases where the full report of a test of such engines is desired.

It is recommended that any report be supplemented by a chart in which the data of the test is graphically presented. (As an example of such a chart as applied to a boiler test, see Volume XXI., p. 104.)

TABLE No. 1.

Data and Results of Steam-Engine Test.

Arranged according to the Complete Form advised by the Engine Test Committee of the American Society of Mechanical Engineers. Code of 1902.

1. Made by ....of..............................
   on engine located at ....
   to determine ....
   ....
2. Date of trial...
3. Type of engine (simple, compound, or other multiple expansion; condensing or non-condensing)..
   ....
4. Class of engine (mill, marine, locomotive, pumping, electric, or other)......

5. Rated power of engine..
6. Name of builders ....
7. Number and arrangement of cylinders of engine ; how lagged ; type of condenser..
8. Type of valves..
9. Type of boiler..
10. Kind and type of auxiliaries (air, circulating, main, and feed pumps; jackets, heaters, etc.)..
....
....

	1st Cyl.	2d Cyl.	3d Cyl.
11. Dimensions of engine......................			
(*a*) Single or double acting..............			
(*b*) Cylinder dimensions :			
Bore.........................in.			
Stroke ....ft.			
Diameter of piston rod..........in.			
Diameter of tail rod.............in.			
(*c*) Clearance in per cent. of volume displaced by piston per stroke :			
Head end........................			
Crank end......................			
Average			
(*d*) Surface in square feet (average)......			
Barrel of cylinder................			
Cylinder heads....................			
Clearance and ports................			
Ends of piston...................			
(*e*) Jacket surfaces or internal surfaces of cylinder heated by jackets, in square feet :			
Barrel of cylinder.................			
Cylinder heads....................			
Clearance and ports................			
Receiver jackets..................			
(*f*) Ratio of volume of each cylinder to volume of high-pressure cylinder.			
(*g*) Horse-power constant for one pound mean effective pressure, and one revolution per minute...........			

12. Dimensions of boilers:
   (*a*) Number ....
   (*b*) Total grate surface................................. sq. ft.
   (*c*) Total water heating surface (external)................ "
   (*d*) Total steam heating surface (external) .... "
13. Dimensions of auxiliaries :
   (*a*) Air pump...
   ....
   (*b*) Circulating pump...
   ....

(c) Feed pumps..
....

(d) Heaters.............................. ....
....

14. Dimensions of condenser..
....

15. Size, length, and number of turns in main steam pipe leading from the boiler to the engine...
....

16. Give description of main features of plant, and illustrate with drawings to be given on an appended sheet.

Total Quantities, Time, Etc.

17. Duration of test...	hours
18. Length of time engine was in motion with throttle open.....	"
19. Length of time engine was running at normal speed.........	"
20. Water fed to boilers from main source of supply.............	lbs.
21. Water fed from auxiliary supplies:	lbs.
(a)	"
(b)	"
(c)	"
22. Total water fed to boilers from all sources	"
23. Moisture in steam or superheating near throttle	per cent. or deg.
24. Factor of correction for quality of steam, dry steam being unity	
25. Total dry steam consumed for all purposes *................	lbs.
26. Total coal as fired †..	"
27. Moisture in coal...	per cent.
28. Total dry coal consumed......................................	lbs.
29. Ash and refuse..	"
30. Percentage of ash and refuse to dry coal....................	per cent.
31. Calorific value of coal by calorimeter test per pound of dry coal, determined by........ ....calorimeter..........	B. T. U.
32. Cost of coal per ton of 2,240 lbs...........................	$

Hourly Quantities.

33. Water fed from main source of supply.......	lbs.
34. Water fed from auxiliary supplies:	
(a)	"
(b)	"
(c)	"
35. Total water fed to boilers per hour..........................	"
36. Total dry steam consumed per hour	"
37. Loss of steam and water per hour due to drips from main steam pipes and to leakage of plant......................	"
38. Net dry steam consumed per hour by engine and auxiliaries..	"
39. Dry steam consumed per hour:	
(a) Main cylinders..	"

* In case of superheated steam engines, determine, if practicable, the temperature of the steam in each cylinder.

† Where an independent superheater is used, this includes coal burned in the superheater.

(*b*) Jackets and re-heaters	lbs.
(*c*) Air pump	"
(*d*) Circulating pump	"
(*e*) Feed-water pump	"
(*f*) Other auxiliaries	"
40. Dry coal consumed per hour:	
(*a*) During running period	"
(*b*) During banking period	"
(*c*) Total	"
41. Injection or circulating water supplied condenser per hour	cu. ft.

Pressures and Temperatures (Corrected).

42. Steam pressure at boiler by gauge	lbs. per sq. in.
43. Steam pipe pressure near throttle, by gauge	"
44. Barometric pressure of atmosphere in inches of mercury	ins.
45. Pressure in first receiver by gauge	lbs. per sq. in.
46. Pressure in second receiver by gauge	"
47. Vacuum in condenser:	
(*a*) In inches of mercury	ins.
(*b*) Corresponding total pressure	lbs. per sq. in.
48. Pressure in steam jacket by gauge	lbs. per sq. in.
49. Pressure in reheater by gauge	"
50. Moisture in steam or superheating at boilers	p. c. or deg. F.
51. Superheating of steam in first receiver	deg. Fahr.
52. Superheating of steam in second receiver	"
53. Temperature of main supply of feed water to boilers	"
54. Temperature of auxiliary supplies of feed water:	
(*a*)	"
(*b*)	"
(*c*)	"
55. Ideal feed-water temperature corresponding to the pressure of the steam in the exhaust pipe, allowance being made for heat derived from jacket or reheater drips	"
56. Temperature of injection or circulating water entering condenser	"
57. Temperature of injection or circulating water leaving condenser	
58. Temperature of chimney gases entering economizer	"
59. Temperature of chimney gases leaving economizer	"
60. Temperature of water entering economizer	"
61. Temperature of water leaving economizer	"
62. Temperature of air in boiler room	"
63. Temperature of air in engine room	"

Data Relating to Heat Measurements.

64. Heat units per pound of feed water, main supply	B. T. U.
65. Heat units per pound of feed water, auxiliary supply	
(*a*)	"
(*b*)	"
(*c*)	"

66. Heat units consumed per hour, main supply	B. T. U.
67. Heat units consumed per hour, auxiliary supplies:	
(a)	"
(b)	"
(c)	"
68. Total heat units consumed per hour for all purposes.........	"
69. Loss of heat per hour due to leakage of plant, drips, etc. ...	"
70. Heat units consumed per hour:	
(a) By engine alone....................................	"
(b) By auxiliaries....................................	"
71. Heat units consumed per hour by the engine alone, reckoned from temperature given in line 55......................	"

Indicator Diagrams.

	1st Cyl.	2d Cyl.	3d Cyl.
72. Commercial cut-off in per cent. of stroke....			
73. Initial pressure in lbs. per sq. in. above atmosphere			
74. Back-pressure at mid-stroke above or below atmosphere in lbs. per sq. in.............			
75. Mean effective pressure in lbs. per. sq. in...			
76. Equivalent mean effective pressure in lbs. per sq. in.:			
(a) Referred to first cylinder..			
(b) Referred to second cylinder...........			
(c) Referred to third cylinder			
77. Pressures and percentages used in computing the steam accounted for by the indicator diagrams, measured to points on the expansion and compression curves.			
Pressure above zero in lbs. per sq. in.:			
(a) Near cut-off.........................			
(b) Near release			
(c) Near beginning of compression........			
Percentage of stroke at points where pressures are measured :			
(a) Near cut-off.........................			
(b) Near release.........................			
(c) Near beginning of compression........			
78. Aggregate M. E. P. in lbs. per sq. in. referred to each cylinder given in heading			
79. Mean back-pressure above zero, lbs. per sq. in.			
80. Steam accounted for in lbs. per indicated horse-power per hour:			
(a) Near cut-off....			
(b) Near release			

81. Ratio of Expansion ....

82. Mean effective pressure of ideal diagram ....lbs. per sq. in.

83. Diagram factor .... per cent.

Speed.

84. Revolutions per minute	rev.
85. Piston speed per minute	ft.
86. Variation of speed between no load and full load	rev.
87. Fluctuation of speed on suddenly changing from full load to no load, measured by the increase in the revolutions due to the change	"

Power.

88. Indicated horse-power developed by main-engine cylinders:	
First cylinder	H. P.
Second cylinder	"
Third cylinder	"
Total	"
89. Brake H. P., electric H. P., pump H. P., or dynamo H. P., according to the class of engine	"
90. Friction I. H. P. by diagrams, no load on engine, computed for average speed	"
91. Difference between indicated H. P. and brake H. P.	"
92. Percentage of indicated H. P. of main engine lost in friction	per cent.
93. Power developed by auxiliaries:	
(*a*)	H. P.
(*b*)	"
(*c*)	"

Standard Efficiency Results.

94. Heat units consumed by engine and auxiliaries per hour:	
(*a*) Per indicated horse-power	B. T. U.
(*b*) Per brake horse-power	"
95. Equivalent standard coal consumed by engine and auxiliaries per hour, assuming calorific value such that 10,000 B. T. U. are imparted to the boiler per lb.:	
(*a*) Per indicated horse-power	lbs.
(*b*) Per brake horse-power	"
96. Heat units consumed per minute:	
(*a*) Per indicated horse-power	B. T. U.
(*b*) Per brake horse-power	"
97. Heat units consumed by engine per hour corresponding to ideal maximum temperature of feed water given in line 55, British standard:	
(*a*) Per indicated horse-power	"
(*b*) Per brake horse-power	"

Efficiency Ratios.

98. Thermal efficiency ratio:	
(*a*) Per indicated horse-power	per cent.
(*b*) Per brake horse-power	"
(*c*) Ratio of efficiency of engine to that of an ideal engine working with the Rankine cycle	"

*Miscellaneous Efficiency Results.**

99. Dry steam consumed per indicated H. P. per hour			
(a) Main cylinder, including jackets			lbs.
(b) Auxiliary cylinders, etc			"
(c) Engine and auxiliaries			"
100. Dry steam consumed per brake H. P. per hour:			
(a) Main cylinders, including jackets			lbs.
(b) Auxiliary cylinders, etc			"
(c) Engine and auxiliaries			"
101. Percentage of steam used by main-engine cylinders accounted for by indicator diagrams:	1st Cyl.	2d Cyl.	3d Cyl.
(a) Near cut-off			
(b) Near release			
102. Dry coal consumed by combined engine and boiler plant per I. H. P. per hour:			
(a) During running period			lbs.
(b) During banking period			"
(c) Total			"
103. Dry coal consumed by combined engine and boiler plant per brake H. P. per hour:			
(a) During running period			"
(b) During banking period			"
(c) Total			"
104. Water evaporated under actual conditions per pound of dry coal			lbs.
105. Equivalent evaporation from and at 212 degrees Fahr. per pound of dry coal			"
106. Efficiency of boilers based on dry coal			per cent.
107. Combined efficiency of boiler and engine plant			"

Additional Calculations Recommended for Special Classes of Steam Engines.

Water-pumping Engines.

108. Duty per 1,000,000 heat units imparted to the boiler	ft. lbs.
109. Duty per 1,000 pounds of dry steam	"
110. Duty per 100 pounds of actual coal consumed by plant	"
111. Number of gallons of water pumped in 24 hours	gals.

Locomotives.

112. Dynamometric horse-power	H. P.
113. "Standard Coal" of 10,000 B. T. U. value consumed, per dynamometric H. P. per hour	lbs.

Electric-light Engines and those Driving Generators for Electric Railways.

114. Current	amperes
115. Electro motive force	volts

* The horse-power on which the above efficiency results (items 94 to 103) are based is that of the main engine, exclusive of auxiliaries.

116. Electrical power generated in watts........................	watts
117. Electrical horse-power generated...........................	H. P.
118. Efficiency of generator....................................	per cent.
119. Heat units consumed per electrical horse-power per hour....	B. T. U.
120. Dry steam consumed per electrical horse-power per hour....	lbs.
121. Dry coal consumed per electrical horse-power per hour:	
(a) During running period..............................	lbs.
(b) During banking period..............................	"
(c) Total...	"

Additional Data.

Add any additional data bearing on the particular objects of the test or relating to the special class of service for which the engine is used. Also give copies of indicator diagrams nearest the mean, and the corresponding scales.

TABLE No. 2.

Data and Results of Standard Heat Test of Steam Engine.

Arranged according to the Short Form advised by the Engine Test Committee of the American Society of Mechanical Engineers. Code of 1902.

1. Made by............................of.................................
   on engine located at...
   to determine ....
   ....
2. Date of trial ....
3. Type and class of engine ; also of condenser ....
   ....

	1st Cyl.	2d Cyl.	3d Cyl.
4. Dimensions of main engine.			
(a) Diameter of cylinder..............in.			
(b) Stroke of piston.................. ft.			
(c) Diameter of piston rod.............in.			
(d) Average clearance...............p. c.			
(e) Ratio of volume of cylinder to high-pressure cylinder.................			
(f) Horse-power constant for one pound mean effective pressure and one revolution per minute.................			

5. Dimensions and type of auxiliaries..
   ....

Total Quantities, Time, Etc.

6. Duration of test..	hours
7. Total water fed to boilers from main source of supply	lbs.
8. Total water fed from auxiliary supplies :	
(a)	"
(b)	"
(c)	"

9.	Total water fed to boilers from all sources.....	lbs.
10.	Moisture in steam or superheating near throttle............	p. c. or deg.
11.	Factor of correction for quality of steam	
12.	Total dry steam consumed for all purposes.................	lbs.

Hourly Quantities.

13.	Water fed from main source of supply....................	"
14.	Water fed from auxiliary supplies :	
	(*a*)	"
	(*b*)	"
	(*c*)	"
15.	Total water fed to boilers per hour......................	"
16.	Total dry steam consumed per hour......................	"
17.	Loss of steam and water per hour due to drips from main steam pipes and to leakage of plant	"
18.	Net dry steam consumed per hour by engine and auxiliaries..	"

Pressures and Temperatures (Corrected).

19.	Pressure in steam pipe near throttle by gauge...............	lbs. per sq. in.
20.	Barometric pressure of atmosphere in inches of mercury	ins.
21.	Pressure in receivers by gauge....................	lbs. per sq. in.
22.	Vacuum in condenser in inches of mercury..................	ins.
23.	Pressure in jackets and re-heaters by gauge.................	lbs. per sq. in.
24.	Temperature of main supply of feed water..................	deg. Fahr.
25.	Temperature of auxiliary supplies of feed water :	
	(*a*)	"
	(*b*)	"
	(*c*)	"
26.	Ideal feed-water temperature corresponding to pressure of steam in the exhaust pipe, allowance being made for heat derived from jacket or reheater drips	"

Data Relating to Heat Measurement.

27.	Heat units per pound of feed water, main supply	B. T. U.
28.	Heat units per pound of feed water, auxiliary supplies :	
	(*a*)	"
	(*b*)	"
	(*c*)	"
29.	Heat units consumed per hour, main supply	"
30.	Heat units consumed per hour, auxiliary supplies :	
	(*a*)	"
	(*b*)	"
	(*c*)	"
31.	Total heat units consumed per hour for all purposes.........	"
32.	Loss of heat per hour due to leakage of plant, drips, etc......	"
33.	Net heat units consumed per hour :	
	(*a*) By engine alone................................	"
	(*b*) By auxiliaries....	"
34.	Heat units consumed per hour by engine alone, reckoned from temperature given in line 26...........................	"

Indicator Diagrams.

	1st Cyl.	2d Cyl.	3d Cyl.
35. Commercial cut-off in per cent. of stroke....			
36. Initial pressure in pounds per square inch above atmosphere...			
37. Back pressure at mid-stroke, above or below atmosphere in pounds per square inch....			
38. Mean effective pressure in lbs. per sq. in....			
39. Equivalent mean effective pressure in lbs. per sq. in.:			
(*a*) Referred to first cylinder			
(*b*) Referred to second cylinder...........			
(*c*) Referred to third cylinder............			
40. Pressures and percentages used in computing the steam accounted for by the indicator diagrams, measured to points on the expansion and compression curves.......			
Pressure above zero in lbs. per sq. in.:			
(*a*) Near cut-off........................			
(*b*) Near release........................			
(*c*) Near beginning of compression			
Percentage of stroke at points where pressures are measured:			
(*a*) Near cut-off			
(*b*) Near release.........................			
(*c*) Near beginning of compression........			
41. Steam accounted for by indicator in pounds per I. H. P. per hour :			
(*a*) Near cut-off.........................			
(*b*) Near release			
42. Ratio of expansion................			

Speed.

43. Revolutions per minute.................................... rev.

Power.

44. Indicated horse-power developed by main-engine cylinders :
First cylinder .... H. P.
Second cylinder........ .. .. "
Third cylinder.. "
Total... "
45. Brake horse-power developed by engine..................... "

*Standard Efficiency and other Results.**

46. Heat units consumed by engine and auxiliaries per hour :
(*a*) per indicated horse-power......................... .. B. T. U.
(*b*) per brake horse-power.............. .... "
47. Equivalent standard coal in lbs. per hour :
(*a*) per indicated horse-power .... lbs.
(*b*) per brake horse-power .... "

* The horse-power referred to above (items 46 50) is that of the main engine, exclusive of auxiliaries.

48. Heat units consumed by main engine per hour corresponding to ideal maximum temperature of feed water given in line 26, British standard :
    (a) per indicated horse-power.......................... B. T. U.
    (b) per brake horse-power.......................... "
49. Dry steam consumed per indicated horse-power per hour :
    (a) Main cylinders including jackets.................... lbs.
    (b) Auxiliary cylinders.............................. "
    (c) Engine and auxiliaries.............................. "
50. Dry steam consumed per brake horse-power per hour :
    (a) Main cylinders including jackets....................
    (b) Auxiliary cylinders.............................. "
    (c) Engine and auxiliaries.............................. "
51. Percentage of steam used by main-engine cylinders accounted for by indicator diagrams, near cut-off of high-pressure cylinder.............................. per cent.

Additional Data.

Add any additional data bearing on the particular objects of the test or relating to the special class of service for which the engine is used. Also give copies of indicator diagrams nearest the mean, and the corresponding scales.

TABLE No. 3.

Data and Results of Feed-water Test of Steam Engine.

Arranged according to the Short Form advised by the Engine Test Committee of the American Society of Mechanical Engineers. Code of 1902.

1. Made by..............................of..............................
   on engine located at..............................
   to determine..............................
   ....
2. Date of trial..............................
3. Type of engine (simple, compound, or other multiple expansion; condensing or non-condensing)..............................
   ....
4. Class of engine (mill, marine, locomotive, pumping, electric, or other).....
5. Rated power of engine..............................
6. Name of builders..............................
7. Number and arrangement of cylinders of engine ; how lagged ; type of valves and of condensers..............................

	1st Cyl.	2d Cyl.	3d Cyl.
8. Dimensions of engine.....................			
(a) Single or double acting..............			
(b) Cylinder dimensions :			
Bore..........................in.			
Stroke..........................ft.			
Diameter of piston rod..........in.			
Diameter of tail rod............in			

	1st Cyl.	2d Cyl.	3d Cyl.
(*c*) Clearance in per cent. of volume displaced by piston per stroke:			
Head end........................			
Crank end........................			
Average........................			
(*d*) Ratio of volume of each cylinder to volume of high-pressure cylinder....			
(*e*) Horse-power constant for one pound mean effective pressure, and one revolution per minute............			

Total Quantities, Time, Etc.

9.	Duration of test..	hours
10.	Water fed to boilers from main source of supply............	lbs.
11.	Water fed from auxiliary supplies:	
	(*a*)	"
	(*b*)	"
	(*c*)	"
12.	Total water fed from all sources............................	"
13.	Moisture in steam or superheating near throttle *............	p. c. or deg.
14.	Factor of correction for quality of steam....................	
15.	Total dry steam consumed for all purposes..................	lbs.

Hourly Quantities.

16.	Water fed from main source of supply.......................	lbs.
17.	Water fed from auxiliary supplies:	
	(*a*)	"
	(*b*)	"
	(*c*)	"
18.	Total water fed to boilers per hour..........................	"
19.	Total dry steam consumed per hour.........................	"
20.	Loss of steam and water per hour due to leakage of plant, drips, etc	"
21.	Net dry steam consumed per hour by engine and auxiliaries..	"
22.	Dry steam consumed per hour:	
	(*a*) Main cylinders..	"
	(*b*) Jackets and reheaters..................................	"

Pressures and Temperatures (Corrected).

23.	Steam pipe pressure near throttle, by gauge.................	lbs. per sq. in.
24.	Barometric pressure of atmosphere in inches of mercury.....	ins.
25.	Pressure in first receiver by gauge..........................	lbs. per sq. in.
26.	Pressure in second receiver by gauge	"

* In case of superheated steam engines, determine, if practicable, the temperature of the steam in each cylinder.

27. Vacuum in condenser:
 (a) In inches of mercury.................................. ins.
 (b) Corresponding total pressure..........................lbs. per sq. in.
28. Pressure in steam jackets by gauge......... ....lbs. per sq. in.
29. Pressure in reheater by gauge............................. "
30. Superheating of steam in first receiver..................... deg. Fahr.
31. Superheating of steam in second receiver.................... "

Indicator Diagrams.

	1st Cyl.	2d Cyl.	3d Cyl.
32. Commercial cut-off in per cent. of stroke....			
33. Initial pressure in lbs. per sq. in. above atmosphere.....................			
34. Back-pressure at mid-stroke above or below atmosphere in lbs. per sq. in.............			
35. Mean effective pressure in lbs. per sq. in....			
36. Equivalent mean effective pressure in lbs. per sq. in. per indicated H. P........			
(a) Referred to first cylinder.			
(b) Referred to second cylinder.			
(c) Referred to third cylinder.			
37. Pressures and percentages used in computing the steam accounted for by the indicator diagrams, measured to points on the expansion and compression curves.......			
Pressures above zero in lbs. per sq. in.:			
(a) Near cut-off			
(b) Near release			
(c) Near beginning of compression.......			
Percentage of stroke at points where pressures are measured:			
(a) Near cut-off.......................			
(b) Near release.......................			
(c) Near beginning of compression.......			
38. Aggregate M. E. P. in lbs. per sq. in. referred to each cylinder given in heading			
39. Mean back-pressure above zero, lbs. per sq. in..............................			
40. Steam accounted for in lbs. per indicated horse-power per hour:			
(a) Near cut-off........................			
(b) Near release........................			

41. Ratio of expansion:
 (a) Commercial...
 (b) Ideal ....

Speed.

42. Revolutions per minute.................................. rev.
43. Piston speed per minute .... ft.

Power.

44. Indicated horse-power developed by main engine cylinders :

First cylinder..	H. P.
Second cylinder..	"
Third cylinder..	"
Total..	"

Efficiency Results.

45. Dry steam consumed per indicated H. P. per hour :

(*a*) Main cylinder, including jackets......................	lbs.
(*b*) Auxiliary cylinders, etc	"
(*c*) Engine and auxiliaries..............................	"

46. Percentage of steam used by main engine cylinders accounted for by indicator diagrams :

	1st Cyl.	2d Cyl.	3d Cyl.
(*a*) Near cut-off......................			
(*b*) Near release......................			

Sample Diagrams.

Copies of indicator diagrams, nearest the mean, with corresponding scales, should be given in connection with table.

RULES FOR CONDUCTING TESTS OF GAS AND OIL ENGINES.* CODE OF 1901.

I. OBJECTS OF THE TESTS.—At the outset the specific object of the test should be ascertained, whether it be to determine the fulfilment of a contract guarantee, to ascertain the highest economy obtainable, to find the working economy and the defects as they exist, to ascertain the performance under special conditions, or to determine the effect of changes in the conditions; and the test should be arranged accordingly.

Much depends upon the local conditions as to what preparations should be made for a test, and this must be determined largely by the good sense, tact, judgment, and ingenuity of the expert undertaking it, keeping in mind the main issue, which is to obtain accurate and reliable data. In deciding questions of contract, a clear understanding in regard to the methods of test should be agreed upon beforehand with all parties, unless these are distinctly provided for in the contract.

II. GENERAL CONDITION OF THE ENGINE.—Examine the engine, and make notes of its general condition, and any points of design, construction, or operation which bear on the objects in

* Hot-air engines are not included in this code, those in the market being of comparatively small size, and seldom tested.

view. Make a special examination of all the valves by inspecting the seats and bearing surfaces, and note their condition, and see if the piston rings are gas-tight.

If the trial is made to determine the highest efficiency, and the examination shows evidence of leakage, the valves and piston rings, etc., should be made tight, and all parts of the engine put in the best possible working condition before starting on the test.

III. DIMENSIONS, ETC.—Take the dimensions of the cylinder, or cylinders, whether already known or not; this should be done when they are hot, and in working order. If they are slightly worn, the average diameter should be determined. Measure, also, the compression space or clearance volume, which should be done, if practicable, by filling the spaces with water previously measured, the proper correction being made for the temperature. (See Section III., Steam Engine Code.)

IV. FUEL.—Decide upon the gas or oil to be used, and if the trial is to be made for maximum efficiency, the fuel should be the best of its class that can readily be obtained, or one that shows the highest calorific power. (See Section IV., Steam Engine Code.)

V.—CALIBRATION OF INSTRUMENTS USED IN THE TESTS.—All instruments and apparatus should be calibrated and their reliability and accuracy verified by comparison with recognized standards. Apparatus liable to change or to become broken during the tests, such as gauges, indicator springs, and thermometers, should be calibrated both before and after the experiments. The accuracy of all scales should be verified by standard weights. In the case of gas or water meters, special attention should be given to their calibration, both before and after the trial, and at the same rate of flow and pressure as exists during the trial.

(a) *Gauges.*—(See Section V., Steam Engine Code.)

(b) *Thermometers.*—(See Section V., Steam Engine Code.)

(c) *Indicator Springs.*—The indicator springs should be calibrated with the indicator in as nearly as possible the same condition as to temperature as exists during the trial. This temperature can usually be estimated in any particular case. A simple way of heating the indicator is to subject it to a steam pressure just before calibration. Compressed air, or compressed carbonic acid gas, are suitable for the actual work of calibration. These gases should be used in preference to steam, so as to bring the conditions as near as possible to those which obtain when the indicators are in actual use. When compressed carbonic acid gas is used, and trouble arises from the clogging of the escape valves with ice, the pipe between the valve and gas tank should be heated. With both air and carbonic acid, the pipes leading to the indicator should also be heated if it is found that they are below the required temperature. The springs may be calibrated for this class of engines under a constant pressure, if desired, and the most satisfactory method is to cover the whole range of pressure through which the indicator acts; first, by gradually increasing it from the lowest to the highest point, and then gradually reducing it from the highest to the lowest point, in the manner which has heretofore been widely followed by indicator makers; a mean of the results should be taken. The calibration should be made for at least five points, two of these being for the pressures corresponding to the maximum and minimum pressures, and three for intermediate points equally distant.

The standard of comparison recommended is the dead weight testing apparatus, a mercury column, or a steam gauge, which has been proved correct by reference to either of these standards.

The correct scale of spring to be used for working out the mean effective pressure of the diagrams is the average based on this calibration, ascertained in the manner pointed out in Section XIV., Steam Engine Code.

(*d*) Gas Meters.—A meter used for measuring gas for a gas engine should be calibrated by referring its readings to the displacement of a gasometer of known volume, by comparing it with a standard gas meter of known error, or by passing air through the meter from a tank in which air under pressure is stored. If the latter method is adopted, it is necessary to observe the pressure of the air in the tank and its temperature, both at the tank and at the meter, and this should be done at uniform intervals during the progress of the calibration. The amount of air passing through the meter is computed from the volume of the tank and the observed temperatures and pressures.

The volume of the gas thus ascertained should be reduced to the equivalent at a given temperature and atmospheric pressure, corrected for the effect of moisture in the gas, which is ordinarily at the saturation point or nearly so. We recommend that a standard be adopted for gas-engine work, the same as that used in photometry, namely, the equivalent volume of the gas when saturated with moisture at the normal atmospheric pressure at a temperature of 60 degrees Fahr. In order to reduce the reading of the volume containing moist gas at any other temperature to this standard, multiply by the factor

$$\frac{459.4 + 60}{459.4 + t} \times \frac{b - (29.92 - s)}{29.4},$$

in which b is the height of the barometer in inches at 32 degrees Fahr., t the temperature of the gas at the meter in degrees Fahr., and s the vacuum in inches of mercury corresponding to the temperature of t obtained from steam tables.

For calibrating water meters refer to Section V., Steam Engine Code.

VI. Duration of Test.—The duration of a test should depend largely upon its character and the objects in view and in any case the test should be continued until the successive readings of the rates at which oil or gas is consumed, taken at say half-hourly intervals, become uniform and thus verify each other. If the object is to determine the working economy, and the period of time during which the engine is usually in motion is some part of twenty-four hours, the duration of the test should be fixed for this number of hours. If the engine is one using coal for generating gas, the test should cover a long enough period to determine with accuracy the coal used in the gas producer; such a test should be of at least twenty-four hours' duration, and in most cases it should extend over several days.

VII. Starting and Stopping a Test.—In a test for determining the maximum economy of an engine, it should first be run a sufficient time to bring all the conditions to a normal and constant state. Then the regular observations of the test should begin, and continue for the allotted time.

If a test is made to determine the performance under working conditions, the test should begin as soon as the regular preparations have been made for starting the engine in practical work, and the measurements should then commence and be continued until the close of the period covered by the day's work.

VIII. Measurement of Fuel.—If the fuel used is coal furnished to a gas producer, the same methods apply for determining the consumption as are used in steam boiler tests. (See Code of Rules for Conducting Boiler Tests, Volume XXI., p. 34.)

If the fuel used be gas, the only practical method of measurement is the use of a meter through which the gas is passed. Gas bags should be placed between the meter and the engine to diminish the variations of pressure, and these should be of a size proportionate to the quantity used. Where a meter is employed to measure the air used by an engine, a receiver with a flexible diaphragm should be placed between the engine and the meter. The temperature and pressure of the gas should be measured, as also the barometric pressure and temperature of the atmosphere, and the quantity of gas should be determined by reference to the calibration of the meter, taking into account the temperature and pressure of the gas. (See Section V. (*d*).)

If the fuel is oil, this can be drawn from a tank which is filled to the original level at the end of the test, the amount of oil required for so doing being weighed; or, for a small engine, the oil may be drawn from a calibrated vessel such as a vertical pipe.

In an engine using an igniting flame the gas or oil required for it should be included in that of the main supply, but the amount so used should be stated separately, if possible.

IX. Measurement of Heat-Units Consumed by the Engine.—The number of heat-units used is found by multiplying the number of pounds of coal or oil or the cubic feet of gas consumed, by the total heat of combustion of the fuel as determined by a calorimeter test. In determining the total heat of combustion no deduction is made for the latent heat of the water vapor in the products of combustion. There is a difference of opinion on the propriety of using this higher heating value, and for purposes of comparison care must be taken to note whether this or the lower value has been used. The calorimeter recommended for determining the heat of combustion is the Mahler, for solid fuels or oil, or the Junker, for gases, or some form of calorimeter known to be equally reliable. (See Poole on "The Calorific Power of Fuels.")

It is sometimes desirable, also, to have a complete chemical analysis of the oil or gas. The total heat of combustion may be computed, if desired, from the results of the analysis, and should agree well with the calorimeter values. (See Section XVII., Boiler Test Code.)

> In using the gas calorimeter, which involves the determination of the volume instead of the weight of the gas, it is important that the results should be reduced to the same temperature as that corresponding to the conditions of the engine trial. The formula to be used for making the reduction is that already given in Section V., *d*.

For the purpose of making the calorimeter test, if the fuel used is coal for generating gas in a producer, or oil, samples should be taken at the time of the engine trial, and carefully preserved for subsequent determination. If gas is used, it is better to have a gas calorimeter on the spot, samples taken, and the calorimeter test made while the trial is going on.

X. Measurement of Jacket Water to Cylinder or Cylinders.—The jacket water may be measured by passing it through a water meter or allowing it to flow from a measuring tank before entering the jacket, or by collecting it in tanks on its discharge. If measuring tanks are used, the same system of arrangement is recommended as that employed for feed water measurements in boiler and steam-engine tests. (See Section XI., Steam Engine Code.)

XI. Indicated Horse-power.—The directions given for determining the indicated horse-power for steam engines apply in all respects to internal combustion engines. (See Section XIII., Steam Engine Code.)

The pipe connections for indicating gas and oil engines should be removed as far as possible from the ports and ignition devices, and made preferably in the cylinder head. The pipes should be as short and direct as possible. Avoid the use of long pipes, otherwise explosions of the gas in these connections may occur.

Ordinary indicators suitable for indicating steam engines are much too lightly constructed for gas and oil engines. The pencil mechanism, especially the pencil arm, needs to be very strong to prevent injury by the sudden impact at the instant of explosion; a special gas-engine indicator is required for satisfactory work, with a small piston and a strong spring.

XII. Brake Horse-power.—The determination of the brake horse-power, which is very desirable, is the same for internal combustion as for steam engines. (See directions given in Section XV., Steam Engine Code.)

XIII. Speed.—The same directions apply to internal combustion engines as to steam engines for the determination of speed, and reference is made to Section XVII., Steam Engine Code, for suggestions on this subject.

In an engine which is governed by varying the number of explosions or working cycles, a record should be kept of the number of explosions per minute; or if the engine is running at nearly maximum load, by counting the number of times the governor causes a miss in the explosions.

One way of mechanically recording the explosions is to attach to the exhaust pipe a cylinder and piston arranged so that the pressure caused by the exhaust gases operates against a light spring and moves a register, which is provided for automatically counting the number.

XIV. Recording the Data.—The time of taking weights and every observation should be recorded, and note made of every event, however unimportant it may seem to be. The pressures, temperatures, meter readings, speeds, and other measurements should be observed every 20 or 30 minutes when the conditions are practically uniform, and at more frequent intervals if they are variable. Observations of the gas or oil measurements should be taken with special care at the expiration of each hour, so as to divide the test into hourly periods, and reveal the uniformity, or otherwise, of the conditions and results as the test goes forward.

All data and observations should be kept on suitably prepared blank sheets or in notebooks.

XV. UNIFORMITY OF CONDITIONS.—When the object of the test is to determine the maximum economy, all the conditions relating to the operation of the engine should be maintained as constant as possible during the trial.

XVI. INDICATOR DIAGRAMS AND THEIR ANALYSIS.—(a) *Sample Diagrams:* Sample diagrams nearest to the mean should be selected from those taken during the trial and appended to the tables of the results. If there are separate compression or feed cylinders, the indicator diagrams from these should be taken and the power deducted from that of the main cylinder.

XVII. STANDARDS OF ECONOMY AND EFFICIENCY.—The hourly consumption of heat, determined as pointed out in Article IX., divided by the indicated or the brake horse-power, is the standard expression of engine economy recommended.

In making comparisons between the standard for internal combustion engines and that for steam engines, it must be borne in mind that the former relates to energy concerned in the *generation* of the force employed, whereas in the steam engine it does not relate to the entire energy expended during the process of combustion in the steam boiler. The steam engine standard does not cover the losses due to combustion, while the internal combustion engine standard, in cases where a crude fuel such as oil is burned in the cylinder, does cover these losses. To make a direct comparison between the two classes of engines considered as complete plants for the production of power, the losses in generating the working agent must be taken into account in both cases and the comparison must be on the basis of the fuel used; and not only this, but on the basis of the same or equivalent fuel used in each case. In such a comparison where producer gas is used, and the producer is included in the plant, the fuel consumption, which will be the weight of coal in both cases, may be directly compared.

The thermal efficiency ratio per indicated horse-power or per brake horse-power for internal combustion engines is obtained in the same manner as for steam engines referred to in Section XXI., Steam Engine Code, and is expressed by the fraction

$$\frac{2545}{\text{B. T. U. per H. P. per hour.}}$$

XVIII. Heat Balance.—For purposes of scientific research, a heat balance should be drawn which shows the manner in which the total heat of combustion is expended in the various processes concerned in the working of the engine. It may be divided into three parts: first, the heat which is converted into the indicated or brake work; second, the heat rejected in the cooling water of the jackets; and third, the heat rejected in the exhaust gases, together with that lost through incomplete combustion and radiation.

To determine the first item, the number of foot-pounds of work performed by, say, one pound or one cubic foot of the fuel, is determined; and this quantity divided by 778, which is the mechanical equivalent of one British thermal unit, gives the number of heat-units desired. The second item is determined by measuring the amount of cooling water passed through the jackets, equivalent to one pound or one cubic foot of fuel consumed, and calculating the amount of heat rejected, by multiplying this quantity by the difference in the sensible heat of the water leaving the jacket and that entering. The third item is obtained by the method of differences; that is, by subtracting the sum of the first two items from the total heat supplied. The third item can be subdivided by computing the heat rejected in the exhaust gases as a separate quantity. The data for this computation are found by analyzing the fuel and the exhaust gases, or by measuring the quantity of air admitted to the cylinder in addition to that of the gas or oil.

XIX. Report of Test.—The data and results of a test should be reported in the manner outlined in one of the following tables, the first of which gives a complete summary when all the data are determined, and the second is a shorter form of report in which some of the minor items are omitted.

XX. Temperatures Computed at Various Points of the Indicator Diagram.—The computation of temperatures corresponding to various points in the indicator diagram is, at best, approximate. It is possible only where the temperature of one

point is known or assumed, or where the amount of air entering the cylinder along with the charge of gas or oil, and the temperature of the exhaust gases, is determined.

If the amount of air is determined for a gas engine, together with the necessary temperatures, so that the volume and temperature of the air entering the cylinder per stroke, and that of the gas are known, we may, by combining this with other data, compute the temperature for a point in the compression curve. In this computation we must allow for the volume of the exhaust gases remaining in the cylinder at the end of the stroke. The temperature at the point in the compression curve where it meets or crosses the atmospheric line will be given by the formula:

$$T = \frac{491.4\ V'}{V'' + V''' + V''''} - 459.4 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (A);$$

where V' is the total volume corresponding to the point where the compression curve meets or crosses the atmospheric line; V'' the volume of the air at atmospheric pressure entering the cylinder during each working cycle, reduced to the equivalent volume at 32 degrees Fahr.; V''' the volume of the gas consumed per cycle reduced to the equivalent at atmospheric pressure and 32 degrees Fahr.; and V'''' the volume of the exhaust gases retained in the cylinder reduced to the same basis. To reduce the actual volumes to those at 32 degrees Fahr., multiply by the ratios of $491.4 \div (T' + 459.4)$ where T' is the observed temperature of the air and of the gas used as fuel. For the exhaust gases retained in the cylinder at the end of the stroke T' may be taken as the temperature of the exhaust gases leaving the engine, provided the engine is not of the "scavenging" type.

Having determined the temperature of a point in the compression curve, the temperature of any point in the diagram may be found by the equation

$$T_1 = (T + 459.4)\ \frac{P_1 V_1}{P V} - 459.4 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (B).$$

Here T_1 is the desired temperature of any point in the diagram where the absolute pressure is P_1 and the total volume V_1; and P and V are the corresponding quantities for the point in the compression line having the temperature T computed from the formula (A).

Formula (B) holds only where the weight of the gases contained in the cylinder is constant. It is also assumed in this formula that the density of the gas compared to air at the same temperature and pressure is the same before and after explosion.

A second method may be employed, provided the air which enters the cylinder is measured. This will allow for any difference in the density of the gas before and after explosion, and more exact values for temperatures on the expansion curve may be obtained than by the first method.

In this method the density of the exhaust gases compared to air at the same temperature and pressure is computed, assuming perfect combustion, and including the effect of the water-vapor present; and from this density the volume of the gases exhausted per cycle is determined. If the volume exhausted per cycle, added to the volume of the gas retained in the clearance space at the end of the stroke, be called V in equation B, and T be the observed temperature of the exhaust gases, this equation may be used for determining the temperature of any point in the diagram in the way already described. This method is more complicated than the first, as it involves the determination of the theoretical density after explosion, but it possesses the advantage that it may be applied to an oil as well as to a gas engine.

A third method of computing the temperature of the various points in the diagram may be employed where analyses of the exhaust gases as well as of the fuel have to be made. This method is more complicated than the first, but, in common with the second, it possesses the advantage that it may be applied to an oil as well as to a gas engine.

In applying the third method the volume of the exhaust gases discharged per working cycle would be given by the formula:

$$V_2 = \frac{1}{D}(R\,w + w) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (C)$$

where D is the density of the exhaust gases at their observed temperature, computed from the analysis, assuming the vapor of water produced through burning the hydrogen in the fuel to be in a gaseous state, R the weight of the air which enters the cylinder per pound of fuel, and w the weight of the fuel consumed per working cycle; the value of R, providing there are no unconsumed hydrocarbons, may be computed by employing the formula:

$$R = \frac{\text{NC}}{.33\,(\text{CO}_2 + \text{CO})} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (D)$$

where N, CO_2, and CO represent the proportions, by volume, of the several constituents of the exhaust gases, and C the weight of carbon consumed and converted to CO_2 or CO per pound of fuel burned, computed from the analysis of the fuel and of the exhaust gases.

Having determined the volume V_2 of the exhaust gases, formula (B) may be used in computing the temperature, in which case T will represent the temperature of the exhaust gases as in the second method, P the pressure of the exhaust, and V the volume of the exhaust gases V_2 discharged per stroke, added to the volume of the gases retained in the cylinder at the end of the stroke.

The value of R given in equation (D) is approximate, on account of the fact that the percentage of N should be that due to the air alone, and not that due to the air in addition to that contained in the fuel gas. Where extreme accuracy is desired, the value found for R may be used to determine the percentage of N which in the analysis of the exhaust gases is due to the N in the fuel gas, and this value may be subtracted from the total N shown by the analysis of the fuel gases, in order to obtain the correct value of N to be used in equation (D).

TABLE No. 4.

Data and Results of Test of Gas or Oil Engine.

Arranged according to the Complete Form advised by the Engine Test Committee, American Society of Mechanical Engineers. Code of 1902.

1. Made by.......................of..................................
   on engine located at......................................
   to determine..
   ....
2. Date of trial...
3. Type of engine, whether oil or gas................................
   ....
4. Class of engine (mill, marine, motor for vehicle, pumping, or other).........
   ....
5. Number of revolutions for one cycle, and class of cycle...................
   ....
6. Method of ignition..
   ....
7. Name of builders..
8. Gas or oil used...
   (*a*) Specific gravity .... deg. Fahr.
   (*b*) Burning point.. "
   (*c*) Flashing point .... "
9. Dimensions of engine :

	1st Cyl.	2d Cyl.
(*a*) Class of cylinder (working or for compressing the charge)		
(*b*) Vertical or horizontal..................		
(*c*) Single or double acting.		
(*d*) Cylinder dimensions..................		
Bore..................in.		
Stroke..................ft.		
Diameter piston rod..................in.		
Diameter tail rod..................in.		
(*e*) Compression space or clearance in per cent. of volume displaced by piston per stroke.....		
Head end..................		
Crank end..................		
Average..................		
(*f*) Surface in square feet (average)..................		
Barrel of cylinders..................		
Cylinder heads..................		
Clearance and ports..................		
Ends of piston..................		
Piston rod..................		
(*g*) Jacket surfaces or internal surfaces of cylinder heated by jackets, in square feet..........		

Barrel of cylinder..........................
Cylinder heads ....
Clearance and ports ....
(*h*) Horse-power constant for one lb. M. E. P., and one revolution per minute.... ....

10. Give description of main features of engine and plant, and illustrate with drawings of same given on an appended sheet. Describe method of governing. State whether the conditions were constant throughout the test.

Total Quantities.

11. Duration of test.... .... hours.
12. Gas or oil consumed.. cu. ft. or lbs.
13. Air supplied in cubic feet .... cubic feet.
14. Cooling water supplied to jackets............ .... "
15. Calorific value of gas or oil by calorimeter test, determined by ....calorimeter.......... .... B. T. U.

Hourly Quantities.

16. Gas or oil consumed per hour........................... ... cu. ft. or lbs.
17. Cooling water supplied per hour............................ lbs.

Pressures and Temperatures.

18. Pressure at meter (for gas engine) in inches of water....... ins.
19. Barometric pressure of atmosphere:
    (*a*) Reading of height of barometer....................... "
    (*b*) Reading of temperature of barometer.................. deg. Fahr.
    (*c*) Reading of barometer corrected to 32° Fahr .... ins.
20. Temperature of cooling water:
    (*a*) Inlet.................... .... deg. Fahr.
    (*b*) Outlet .... "
21. Temperature of gas at meter (for gas engine)................ "
22. Temperature of atmosphere:
    (*a*) Dry-bulb thermometer.................................. "
    (*b*) Wet-bulb thermometer .... "
    (*c*) Degree of humidity .... per cent.
23. Temperature of exhaust gases.... .... deg. Fahr.
    How determined..

Data Relating to Heat Measurement.

24. Heat units consumed per hour (lbs. of oil or cu. ft. of gas per hour multiplied by the total heat of combustion).......... B. T. U.
25. Heat rejected in cooling water:
    (*a*) Total per hour.................................... "
    (*b*) In per cent. of heat of combustion of the gas or oil consumed....... .... per cent.
26. Sensible heat rejected in exhaust gases above temperature of inlet air:
    (*a*) Total per hour..................................... B. T. U.
    (*b*) In per cent. of heat of combustion of the gas or oil consumed.. per cent.

27. Heat lost through incomplete combustion and radiation per hour:		
(*a*) Total per hour....................................		B. T. U.
(*b*) In per cent. of heat of combustion of the gas or oil consumed..		per cent.

Speed, Etc.

28. Revolutions per minute....................................		rev.
29. Average number of explosions per minute..................		
How determined		
30. Variation of speed between no load and full load............		rev.
31. Fluctuation of speed on changing from no load to full load measured by the increase in the revolutions due to the change.		

Indicator Diagrams.

	1st Cyl.	2d Cyl
32. Pressure in lbs. per sq. in. above atmosphere:		
(*a*) Maximum pressure..........................		
(*b*) Pressure just before ignition.....		
(*c*) Pressure at end of expansion....................		
(*d*) Exhaust pressure....................		
33. Temperatures in deg. Fahr. computed from diagrams:		
(*a*) Maximum temperature (not necessarily at maximum pressure).............................		
(*b*) Just before ignition...........................		
(*c*) At end of expansion........		
(*d*) During exhaust..............................		
34. Mean effective pressure in lbs per sq. in...............		

Power.

35. Power as rated by builders:		
(*a*) Indicated horse-power..............................		H. P.
(*b*) Brake..		"
36. Indicated horse-power actually developed:		
First cylinder..		"
Second cylinder..		"
Total.................		"
37. Brake H. P., electric H. P., or pump H. P., according to the class of engine......................................		"
38. Friction indicated H. P. from diagrams, with no load on engine and computed for average speed		"
39. Percentage of indicated H. P. lost in friction................		per cent.

Standard Efficiency Results.

40. Heat units consumed by the engine per hour:		
(*a*) Per indicated horse-power...........................		B. T. U.
(*b*) Per brake horse-power........................ ...		"
41. Heat units consumed by the engine per minute:		
(*a*) Per indicated horse-power...........................		
(*b*) Per brake horse-power..............................		"

42. Thermal efficiency ratio:
  (a) Per indicated horse-power .... per cent
  (b) Per brake horse-power .... "

Miscellaneous Efficiency Results.

43. Cubic feet of gas or lbs. of oil consumed per H. P. per hour:
  (a) Per indicated horse-power ....
  (b) Per brake horse-power ....

Heat Balance.

44. Quantities given in per cents. of the total heat of combustion of the fuel:
  (a) Heat equivalent of indicated horse power .... per cent.
  (b) Heat rejected in cooling water .... "
  (c) Heat rejected in exhaust gases and lost through radiation and incomplete combustion .... "
  Sum = 100 "

Subdivisions of Item (c):
  (c1) Heat rejected in exhaust gases .... "
  (c2) Lost through incomplete combustion .... "
  (c3) Lost through radiation, and unaccounted for .... "
  Sum = Item (c) ....

Additional Data.

Add any additional data bearing on the particular objects of the test or relating to the special class of service for which the engine is to be used. Also give copies of indicator diagrams nearest the mean and the corresponding scales. Where analyses are made of the gas or oil used as fuel, or of the exhaust gases, the results may be given in a separate table.

TABLE No. 5.

Data and Results of Standard Heat Test of Gas or Oil Engine.

Arranged according to the Short Form advised by the Engine Test Committee, American Society of Mechanical Engineers. Code of 1902.

1. Made by .... of ....
  on engine located at ....
  to determine ....
  ....
2. Date of trial ....
3. Type and class of engine ....
  ....
4. Kind of fuel used ....
  (a) Specific gravity .... deg. Fahr.
  (b) Burning point .... "
  (c) Flashing point .... "

5. Dimensions of engine:

	1st Cyl.	2d Cyl.
(a) Class of cylinder (working or for compressing the charge)..		
(b) Single or double acting		
(c) Cylinder dimensions:		
Bore.................................. in.		
Stroke..................................ft.		
Diameter piston rod........................in.		
(d) Average compression space, or clearance in per cent..................................		
(e) Horse-power constant for one lb. M. E. P. and one revolution per minute....................		

Total Quantities.

6. Duration of test.. hours.
7. Gas or oil consumed...................................... cu. ft. or lbs.
8. Cooling water supplied to jackets ....
9. Calorific value of fuel by calorimeter test, determined by ....calorimeter................................ B. T. U.

Pressures and Temperatures.

10. Pressure at meter (for gas engine) in inches of water........ ins.
11. Barometric pressure of atmosphere:
    (a) Reading of barometer...................................... "
    (b) Reading corrected to 32 degs. Fahr........................ "
12. Temperature of cooling water:
    (a) Inlet.. deg. Fahr.
    (b) Outlet... "
    (c) Degree of humidity .... "
13. Temperature of gas at meter (for gas engine)................ "
14. Temperature of atmosphere:
    (a) Dry bulb thermometer................................... "
    (b) Wet bulb thermometer................................... "
15. Temperature of exhaust gases................................ "

Data Relating to Heat Measurement.

16. Heat units consumed per hour (pounds of oil or cubic feet of gas per hour multiplied by the total heat of combustion)... B. T. U.
17. Heat rejected in cooling water per hour..................... "

Speed, Etc.

18. Revolutions per minute...................................... rev.
19. Average number of explosions per minute ....

Indicator Diagrams.

20. Pressure in lbs. per sq. in. above atmosphere:

	1st Cy..	2d Cyl.
(a) Maximum pressure..................................		
(b) Pressure just before ignition......................		

(*c*) Pressure at end of expansion....................
(*d*) Exhaust pressure.............................
(*e*) Mean effective pressure........................

Power.

21. Indicated horse-power:
First cylinder...................................... H. P.
Second cylinder.................................... "
Total... "
22. Brake horse-power.................................... "
23. Friction horse-power by friction diagrams .... "
24. Percentage of indicated horse-power lost in friction.......... per cent.

Standard Efficiency, and Other Results.

25. Heat units consumed by the engine per hour:
(*a*) Per indicated horse-power........................ B. T. U.
(*b*) Per brake horse-power............................ "
26. Pounds of oil or cubic feet of gas consumed per hour:
(*a*) Per indicated horse-power........................ lbs. or cu. ft.
(*b*) Per brake horse-power............................ "

Additional Data.

Add any additional data bearing on the particular objects of the test or relating to the special class of service for which the engine is to be used. Also give copies of indicator diagrams nearest the mean, and the corresponding scales.

No. 974.*

DISCUSSION ON THE PRELIMINARY FORMS OF THE REPORT OF COMMITTEE ON STANDARDIZING ENGINE TESTS.

Dr. R. H. Thurston.—I have read the report and the attached matter with great interest and pleasure. It impresses me as a well-considered, thoroughly well-digested study of the subject assigned to the Committee. The reduction of the standard to its final and ultimate form, the mechanical equivalent of heat, and the employment of the measure of the number of thermal units per horse-power-hour as the gauge of efficiency of the system, is logical and exact and the reminder that it in no way interferes with the use, each in its proper place, of the more familiar and usual measures of economical performance is timely.

The fact that there may be many "efficiencies," and that there is a series of such quantities, in the operation of the heat-engines, from the point at which combustion occurs up to the final delivery of the power of the engine to the machinery of transmission, and from the latter to the point of receipt of energy by the driven mechanism, is too seldom understood. It cannot be too strongly impressed upon the average reader of the Code that when "efficiency" is referred to it is necessary to have it distinctly understood which of the efficiencies in the series, or what total efficiency, is intended. I think that the Report of the Committee of the British Institution of Civil Engineers on the Standard Efficiency may be improved, somewhat, in this respect, and the action of this Committee is, in my opinion, wise in abstaining from its adoption without qualification. Each of the efficiencies has its place and its purpose, and that form of expression is adopted by the engineer which is appropriate to his work at the moment. He sometimes finds it necessary to employ the *absolute* measure, which is the Joule Equivalent, as a standard of efficiency; sometimes the *relative* efficiency of a Carnot cycle becomes the standard; sometimes

* Presented at the meetings at Milwaukee (May, 1901), New York (December, 1901), and Boston (May, 1902).

the proposed relative standard, that of the Rankine or Clausius cycle without compression and with complete expansion; sometimes it should be the relative efficiency of the ideal cycle which the indicator-diagram of the engine studied most exclusively approximates which is needed for comparative study and for a standard of perfection of the engineer's work.* I think that this logical relation and sequence of the efficiencies cannot be too carefully kept in view and the necessity of exact definition of any form of that much abused expression cannot be too constantly kept in mind. As I remarked in the discussion of the preliminary draft of this report:—

"Each has its proper place and purpose, and neither can stand for another, any more than the Rankine and Clausius ideal diagrams, sometimes confused, can be substituted the one for the other."

The plan of this report seems to me excellent and the system of small type comment most helpful. The whole will serve admirably as a hand-book relative to its subject.

In section ix, the Committee advise that no deduction be made for wastes by auxiliaries "unless these are shown by the test to be unduly wasteful." I should think it wise further to provide that, in such cases, the method of waste and its extent, as compared with the wastes of the main engine or other standard of known value be reported definitely.

The recommendations of the Committee regarding the avoidance of the use of the three-way cock, except where absolutely unavoidable, are most excellent. We have had a large experience in our regular laboratory work with locomotive testing and have never had any serious difficulty in securing the use of a pair of indicators; but, even then, the connections are often longer than could be wished. As stated in the preliminary discussion, "Making daily trips on the D. L. & W. Railroad, between Ithaca and Owego, at various speeds and with various weights of train, we find no difficulty in this direction, or, in fact, in getting all the data we seek, including power, speed, steam, and gas temperatures, water-supply, and quality of steam."

I am glad to see that the Committee has observed the desirability of defining the point of cut-off on the ordinary indicator-diagram and has endeavored to give it an authoritative location. It is of

* Proc. Brit. Inst. C. E. March 24, 1896; Journal Franklin Institute, Dec. 1896; Manual of the Steam-Engine, 4th Edit., Vol. I., Chap. viii.

less importance to identify the true equivalent cut-off than it is to fix some definite and acceptable convention regarding it. I think the Committee have good reason to place the point as reported, and hope that the method proposed will become universally recognized as standard.

I am not as confident regarding the acceptance of the "hyperbolic curve" as a standard expansion-line. I think there are occasions when the "curve of constant weight," which can be easily obtained and accurately laid down by reference to the steam-tables, would be preferable, if not necessary. With large ratios of expansion, also, either the adiabatic, or the curve of constant weight, or the actual curve of the diagram, will be found to depart very considerably from the equilateral hyperbola. Rankine's hyperbola $pv^{\frac{10}{9}} = \text{const.}$, in such cases departs widely from the others. I think that the values of n in $pv^n = \text{const.}$, $n = 1$; $n = 1.135$, $n = 1.0646$, all have their places in such discussions, like the various efficiencies; but I think there is no place for $n = \frac{10}{9}$. The most generally useful and usually most suitable standard, in my opinion, is that in which $n = 1.0646$; since it always gives a measure of the specific volume of the steam and of the quantity of the "cylinder-condensation" at any given point during expansion. The equilateral hyperbola, however, will often be found convenient for approximations, with low ratios of expansion.

The adoption of the hour as the unit of time will prove, I am sure, a good move. It is often very annoying to find the time-unit, in the same report, to be stated as the second in one set of data and the hour in another, without reduction of the one to the other measure.

I desire to be permitted to congratulate the Committee on the excellent form which their report has taken, and to express appreciation of the conscientious work, the patience, the care, and the expert skill which have been embodied in what I anticipate and hope will prove a standard and a guide, for many years, for all who have to do with this kind of work.

Mr. H. Wade Hibbard.—I have never yet, in my personal experience of ten years, found it to be "impracticable" to use two indicators on each cylinder of two-cylindered locomotives in road tests. The three-way cock should be omitted. The indicator pipes need not, as a rule, be over one foot in length. The two indicators are placed outside the side line of the slide-valve steam chest. This is in criticism of a small portion of section xiii., the paragraph of five lines in large type between the two long paragraphs in small type.

Mr. A. F. Nagle.—Referring to paragraph 2, "the term 'engine' as here used should include the entire equipment which is concerned in the production of the power, embracing the main cylinder or cylinders, the jacket and reheaters, the air, circulating, and boiler-feed pumps, if steam-driven, and any other steam-driven mechanism necessary to the working of the engine," it should be noted that the Committee has made no explanation of what shall be done to calculate the efficiency of engines where the auxiliary machinery is electrically-driven instead of steam-driven. It seems to me that the committee ought to take this matter up and define how the calculation should be made with this changed application of power. Possibly they thought it such an uneconomical method—a mere fad in engineering practice—that it would not survive long enough to be treated respectfully by them; but it is here at present, and I think the Committee should provide for it. Fortunately, electric power is far more easily measured than steam power, and, for that reason, would not the simplest way be to deduct from the electrical output of the main generator the amount of current used to drive these auxiliaries (assuming the engine to drive a generator)?

It is a small matter, but I would suggest that the notation for high and low pressure cylinders be expressed in small letters instead of capitals. The capitals "H" and "P" are so commonly used for the abbreviation of horse-power that it will be well not to use them elsewhere, if it can be avoided.

In passing, I should like to have the committee define the word "preheater," now used by some engineers. What is meant by it, I believe, is a feed-water heater inserted in the exhaust pipe between the low-pressure cylinder and the condenser. There is at least one engine, the Nordberg, where these so-called preheaters are introduced between the different expansion cylinders. We have reheaters for heating steam in its passage from one cylinder to another in multiple-cylinder engines. Shall we have preheaters for heating feed water, and how shall we distinguish between a preheater and the ordinary feed-water heater? Occasionally, for many years past, a feed-water heater has been placed in the exhaust pipe of a condensing engine, although its utility was questioned until the more accurate engineering practice of the day established its exact value. Shall we now give up that name, and call it a preheater? Shall we continue to speak of exhaust steam feed-water heaters when applied to non-condensing engines, and call them preheaters when used in condensing engines? It is an exhaust steam feed-water heater in either case. Why, then, give it a new name? In the case of the Nordberg system of heating the feed water in successive stages by the exhaust steam from each one of the cylinders of a multiple-cylinder engine, there may be a propriety in naming them preheaters, but I am not sure that even in that case it is necessary. It is a new word in our nomenclature, and I would like to know whether the Committee would endorse its use; and, if so, to have them clearly define its meaning.

Mr. W. W. Christie.—John Perry in his book on the steam engine, pages 312, 313, says in part that "the latest determination of the average heat energy required to raise one pound of water one degree (called Joule's equivalent) from 0 degree C. to 100 degrees C., is by Prof. O. Reynolds, and is 1,399 foot-pounds. Notice that Regnault's heat given to water from 0 degree C. to 100 degrees C. is 100.5 units. According to Reynolds this is equivalent to 139,900 foot-pounds."

For 100 units it would be 139,300; for one unit, 1,393 foot-pounds Centigrade scale, or 774 on the Fahrenheit scale—not 778, as used in section xxi. of the final report, nor 772, as is sometimes given.

What I should like to have made clear is, why is 778 used, and if no satisfactory reason can be given, why should we not use 774 in our engine-efficiency calculations? The same remarks would apply also to section xvii. of "Rules for Conducting Tests of Gas and Oil Engines."

DISCUSSIONS RECEIVED SINCE THE MEETING OF THE SOCIETY IN MILWAUKEE.

Mr. Arthur J. Frith.—Referring to the question, "Whether the higher or lower heat of combustion should be used in computing the heat consumption of an engine," I understand the question to refer to internal-combustion engines, and that the *higher heat of combustion* is the total number of British thermal units of the fuel when completely consumed; while the lower heat of combustion is obtained by deducting, from the above, the latent heat of the water vapor contained in the products of combustion.

That the British thermal units represented by the latent heat of the water vapor is an amount of energy that has no useful effect on the thermo-dynamic cycle seems to be evident, and it appears that it is immaterial whether the water vapor is formed during the progress of combustion, by the chemical union of the elements of the fuel, and the oxygen of the air supplied for its consumption, or whether it was a percentage of liquid water, originally a part of the fuel, and afterwards vaporized by the burning of the fuel; its presence in the exhaust gases at a temperature far above its point of vaporization, represents energy present as sensible heat and as latent heat, the sensible heat of the steam being as capable of performing useful work on the piston as if it were present in a fixed gas; but the latent heat has neither raised the temperature nor increased the pressure or volume beyond that of any fixed gas with about the same amount of sensible heat, and has been, so far as the working cycle is concerned, absolutely inert. *Its expenditure in this manner* is, therefore, evidently detrimental to the power plant—that is, to the engine and whatever method is used for burning the fuel—and the only question that is pertinent, is how and to what item should you charge this loss in figuring the heat balance in a thermo-dynamic discussion.

If the object of a trial is simply a commercial one to determine the quantity of a particular fuel used in a particular engine, then the question is immaterial, and, as the simplest method, the higher heat of combustion should be used to obtain the final efficiency and should be entered in a subheading in a standard table for engine tests. But when the object is to be able to compare the trial of one engine with that of another, or the performance of like engines under varying conditions, it is important that items that will obscure the actual conditions should be eliminated. As English tests of gas engines are based on the lower heat of combustion, ours would not be strictly comparable unless in a standard system of testing there be a heading for the lower heat. Even if the higher heat be used and recorded under a sub heading.

The presence of water, or the formation of water vapor, is no fault of the mechanism of the engine. It is characteristic of the fuel used, and if it occasions a loss of energy, that loss should be charged to the fuel in such a way as not to militate against the performance of the engine. Now this is what the use of the lower heat of combustion does ; it gives the efficiency of the engine, as determined by the actual number of effective British thermal units delivered to the engine, making the efficiency obtained independent of any water in the particular fuel used. The effect on the fuel might be represented as a percentage such as efficiency of fuel, so that, for commercial purposes, the product of engine efficiency by fuel efficiency would give efficiency of power plant as against the true efficiency of the engine.

The argument that "because in an oil or gas engine the steam does its proportion of work in the cylinder along with the other gases, it is therefore unfair to deduct the heat contained in the amount exhausted," confuses the different conditions of steam and gas engines. Of course, the steam does its proportion of work in the cylinder, and in doing so expends part of its sensible heat, and the remaining sensible heat is accounted for in the heat balance undisturbed. It is the latent heat only that it is proposed to deduct, and the latent heat has been inert through the entire cycle and does not belong to the problem of an engine using a non-condensing medium. In this it differs from a steam engine, where steam condenses in the cylinder and the latent heat must be considered.

In the discussion of the trials of steam engines it is proposed to use, in the heat discussion, under certain circumstances, a standard boiler with an efficiency of 80 per cent., and a standard coal with a calorific value of 12,500 British thermal units; this is done, I believe, in order that the efficiency of the engine may be expressed in terms which will be independent of any particular boiler or particular coal, and thus tests under a large variation of circumstances may be compared. Why then should we not do the same for the internal-combustion engine, use a unit of measurement that will give the efficiency of the engine independent of an accidentally inert but disturbing constituent of the fuel, and, if the efficiency of power plant be desired, multiply it by the efficiency of the fuel to obtain an efficiency of the two combined? And is it not possible and desirable to have a standard gas and a standard oil of stated effective calorific value to which the efficiency of gas and oil engines may be referred for the purpose of mutual comparison, while various oils, and natural, producer, or other gases, would have efficiencies as compared to these standards?

Mr. F. H. Ball.—Referring to the part of the report, Section xx., where diagrams are given for purposes of illustration, one of the lines of the diagram is supposed to represent "pressure at throttle." Nothing is said as to how this throttle pressure is to be determined. The Committee must be aware that the throttle pressure does not correspond with the gauge pressure in the boiler; neither does it correspond with the highest pressure shown in the cylinder; how then is the throttle pressure to be determined in conducting an engine trial? It is not customary to attach an indicator to the steam pipe at the throttle (although this is an excellent thing to do), but even if indicator-diagrams are taken from the throttle, a widely fluctuating pressure will be shown by these diagrams, a minimum pressure appearing during the time of admission to the cylinder, and when cut-off takes place a violent rise in pressure occurs, sometimes reaching the full gauge pressure, or going above it, by reason of an action of the steam similar to the well-known "water hammer" in hydraulics. Any one who has taken these steam pipe diagrams must be aware that they often show a fluctuation of 10 or 15 pounds in the pressure, and in some cases even more. The Committee must be aware of this state of things, and yet we are not told how to locate the line representing pressure at the throttle. If the method of locating this line is left to the judgment of each engineer, what prospect is there of any similarity in the system adopted, and even if a steam pipe diagram were available in each case, what does the Committee advise as standard practice in determining throttle pressure when it fluctuates even to the extent of 10 pounds during each stroke. It is certainly unfortunate that a committee of the Society should make recommendations to engineers, with a view to standardizing the reports of engine trials, and leave a matter of this kind entirely without any possible standard. Would it not have been better to have used the *gauge* pressure at the boiler in the proposed theoretical diagrams, rather than to guess at the throttle pressure? Having adopted this, the practice would be absolutely uniform in every case, and where a large difference is found between the boiler pressure and the highest pressure on the piston, then a steam pipe diagram should certainly be taken to determine to what extent this loss is due to piping, and to what extent it is due to wire drawing in the ports of the engine.

While on the subject of pressures, it seems to me that the Committee is making a mistake, also, in regard to *exhaust* pressures. The same uncertainty which exists as to the pressure in the steam pipe at the throttle, exists also in regard to the pressure in the exhaust pipe where it attaches to the engine, and any attempt to use the pressure in the exhaust pipe in constructing theoretical diagrams for comparison, will lead to the same confusion which I have described in the matter of determining the steam pressure at the throttle. Even if an indicator is attached to the exhaust pipe near the engine, it will show a considerable fluctuation, so that the engineer must decide what should be the exhaust pressure, and of course there is no reason to expect any similarity in the work of different engineers in determining a question of this kind. If the Committee had thought best to recommend the use of the *atmospheric* pressure in the case of non-condensing engines, and of the pressure in the *condenser* in the case of condensing engines, the practice would then be uniform, and the work done by different engineers would correspond in the matter of these theoretical diagrams used for comparison. Of course in a case where a great discrepancy appears between the lowest pressure on the piston and the pressure at the end of exhaust pipe (whether discharging into the atmosphere or the condenser) then an investigation should be made with the indicator, to determine to what extent the piping is responsible for this difference.

If the recommendations of this Committee are to be generally adopted by engineers, the methods must be clearly described in terms so explicit as to leave no excuse for any difference in the work done in conformity with the proposed standards, and for that reason I think that part of the report relating to pressures is very faulty. It seems to me, also, that it is of the greatest importance that the standards proposed by this Committee should be as few in number as possible; for instance, is it not a serious mistake that this Committee should recommend *two* different systems for determining the "ratio of expansion?" It is proposed to adopt a "commercial ratio" of expansion and also an "ideal" ratio of expansion.

The result of this confusion about the ratios of expansion is almost certain to be that the whole matter will be disregarded by engineers and will become a dead letter. Instead of the two systems proposed by the Committee, if it had been proposed to determine the ratio of expansion by comparing the gauge pressure with the theoretical terminal pressure of the expansion curve, which should be obtained by continuing the expansion curve from the point of release to the end of the diagram, the method would have been easily understood, easily remembered, and would be more easily used than any of the proposed methods. Referring to Fig. 130, it will be seen that in order to determine the "ideal ratio" of expansion it is necessary to construct the expansion curve by a theoretical process from O to S, and also the compression curve by a similar process from P to R. Any error in these curves must result in a corresponding error in the length of the line RS. If instead of this proposed method the Committee had recommended a method which requires only the theoretical continuation of the expansion curve from the point of release to the end of the diagram, the possible error would certainly be less than it would be in the construction of *two* theoretical curves of considerable greater length, as in the method proposed by the Committee.

Referring again to Fig. 130, suppose the terminal pressure, already referred to, is 20 pounds above absolute vacuum, and suppose the boiler pressure or gauge pressure is 120 pounds above vacuum, then the ratio of expansion is $\frac{120}{20} = 6$.

This certainly is simpler than either of the proposed standards, and less liable to error. Why do we require anything more in regard to ratios of expansion?

Diagram Factors.

The Committee has thought best to propose three diagram factors; one called the "commercial" factor and two called the "ideal" factor, without any special name to distinguish between the two ideal factors. What I have just said about the undesirability of several standards for measuring the ratios of expansion, applies also to the proposed standards for diagram factors, and I think the report of the Committee would have been stronger and better received by engineers if only a single factor had been recommended, but I think the same criticism which I have made regarding throttle pressure and exhaust pressure, in connection with the ratios of expansion, will apply to this case also, and it would have been better to have used gauge pressure and the pressure at the end of exhaust pipe.

In Fig. 137 *, the proposed "Commercial" ratio is applied to the combined diagrams from a compound engine. I heartily approve the plan of comparing the areas of the actual diagrams with the area of a theoretical diagram representing the expansion of an equal volume of steam *AR*. Mr. Sederholm, in his discussion of this report at the Milwaukee meeting, calls attention to the fact that it is only the steam represented by the volume between the expansion and compressed curves that has really been used, and this is true. It is, therefore, absurd to compare this with a larger volume, which is just what is done when all the steam between the clearance line and the expansion curve is used as a theoretical basis of comparison.

The proposed method of making the line *ML* equal to *QE* is certainly correct, because we are supposed to be following the theoretical expansion of the volume *AR* continuously to the pressure at *H*. It seems to me, however, that the proposed plan would be improved if the offset in the theoretical diagram at receiver pressure was eliminated, so that the expansion and compression curves of the theoretical diagram would be continuous. The diagram factor would be exactly the same in either case, but there is quite a difference in the appearance of the diagram. Also, it is a much simpler process to construct the theoretical diagram without offsets in its curves.

The object of combining diagrams from a compound engine is to compare the performance of the engine as a whole with the expansion of an equal volume of steam to the same terminal pressure in a single cylinder. The theoretical diagram used as a basis of comparison should therefore be a single-cylinder diagram. It will be found convenient to use the clearance of the low-pressure cylinder in making the compression curve of the theoretical diagram, and, in reducing the length of high-pressure diagram by the cylinder ratio, it may be constructed so that its compression curve coincides with the curve of the theoretical diagram. This subject is presented at some length in vol. xv. of *Transactions* of the American Society of Mechanical Engineers, page 407.

The method proposed by the Committee, which produces the offsets in the curve, does not result in any error in the factor,

* This figure formed part of the report at the time of Mr. Ball's discussion. It was removed from the report and is here reproduced.

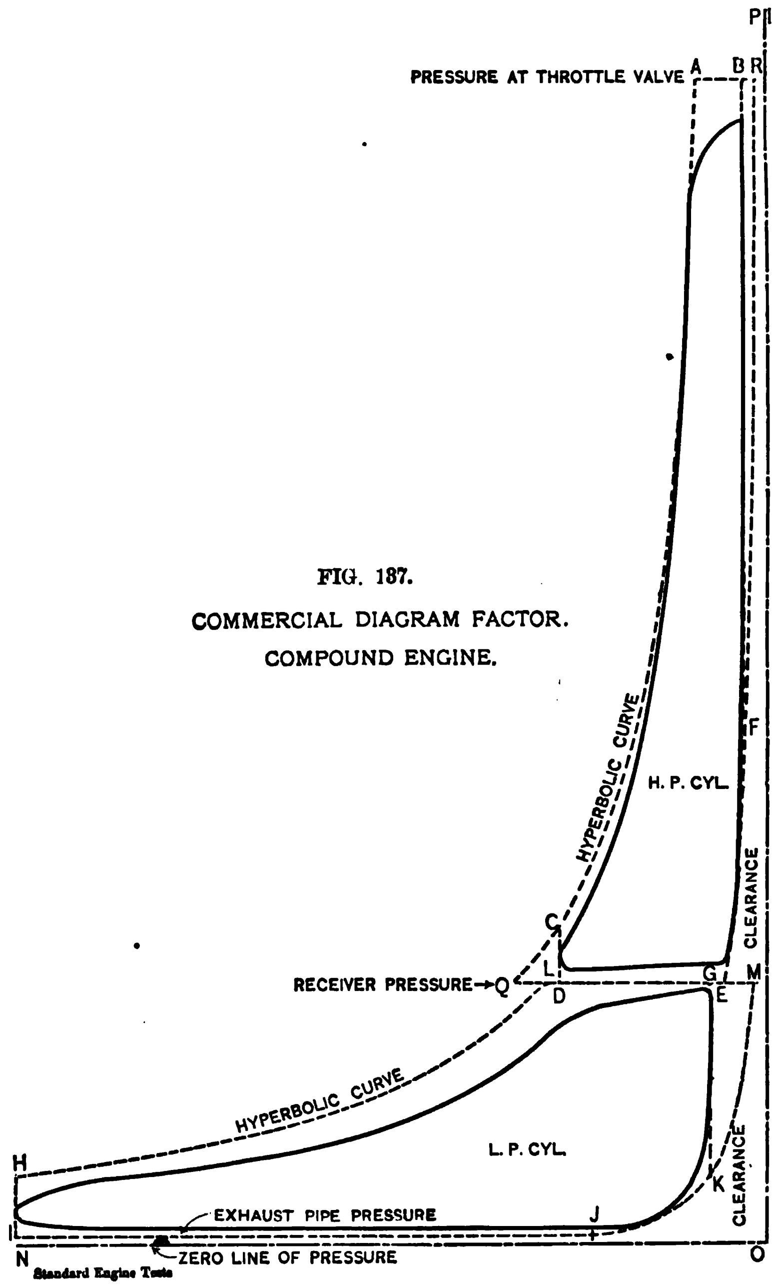


FIG. 187.

COMMERCIAL DIAGRAM FACTOR.

COMPOUND ENGINE.

or at least none due to these curves; but I think any method of measurement which does not include the area of the triangle *Q C D* is wrong and should be corrected. It must be borne in mind that when these diagrams are combined we are not seeking a diagram factor for each cylinder separately, but for the combined performance compared with a corresponding total expansion in a single cylinder. If we were seeking the diagram factor of the high-pressure diagram only, we should use the line *C D* as the end of the diagram, and if we were seeking the diagram factor of the low-pressure diagram we should not use *M L* as the initial volume; but when the diagrams are combined then *M L* is the correct volume at receiver pressure, and the area of *Q C D* must also be included.

Mr. William Kent.—There is only one point I wish to emphasize, which is that I thoroughly approve of the action of the Committee in recommending in paragraph 2 of the Report that in determining the total heat of combustion of a fuel no deduction is to be made for the latent heat of the water vapor in the products of combustion.

The figures for heating value of coal generally adopted in America and in France are those actually found by the Mahler or other oxygen calorimeter. I have gone into the argument to a considerable extent in my recent book on Steam Boiler Economy, pages 22 to 24, showing the great difficulties we get into when we try to use the lower heat value, that is, the total heating value less the latent heat, as the Germans do. I think it quite likely that the latent heat discharged by a gas engine may some day be made use of by some form of economizer or heater of the air or of the oil or gas, and in the case of boiler practice it may already be made use of by an economizer when the water is very cold. The scientific method is the one which the French and the Americans have generally used. I do not think we should adopt the German or English method at all. The total calorimetric heat value is now universally adopted in French and American literature, and I see no reason why we should change it.

I would ask the Committee before finally printing their report to amend the third paragraph of section vii. It says that the test of a complete plant embracing boilers and engines should continue at least twenty-four hours, but that a continuous coal test of a boiler engine should be at least ten hours duration. These two statements thus placed together are ambiguous. If the feed water test of an engine should last five hours, and a continuous coal test of a boiler and engine ten hours, what kind of a test is it which should be run twenty-four hours?

Mr. Wm. O. Webber.—I have carefully read over the final report, Paper 973, and wish to add my testimony to that of Dr. Thurston as to the thoroughness with which this paper has been prepared.

I can see only one or two points of minor importance to criticise. One in the notes of section viii., "Starting and Stopping of Engine Test." In the notes it says, "It is important, also, to refrain from blowing off the water column or its connecting pipes, either during the progress of the test or for a period of an hour or more prior to its beginning." This does not seem to me to be quite strong enough. I should change the word "important" for "imperative."

Also in regard to marking the height of water in the gauge glass in a convenient way. I would strongly advise, if a paper scale is used, that the height of the water at the commencement of a test be marked on the paper scale with a pencil so as to be absolutely fixed, or if a paper scale be not used, that this height be marked by tying a colored string around the water glass with the ends then carefully fastened to one of the protecting rods at the side of the glass and sealed with sealing wax so that it cannot be moved, and that the water in the boilers be kept during the test as nearly as possible at this fixed height.

It certainly does make a difference, both in regard to the surface of the steam escaping space in a boiler and the rapidity with which steam may be made, and also as to the priming of a boiler and the entrainment of water into the cylinders of an engine, if there is a great variation in the level of the water in the boilers during the test.

Referring to section xv., "Brake Horse-Power," I have repeatedly used both the rope brakes and band brakes, and wish to put myself on record as believing that there may be some other forms of brake which are more generally suited to exact conditions than the rope brake.

It would seem to the writer that a form of band brake such as is shown in vol. xv., page 62, of the *Transactions*, or some simple modification of a band brake might be used, which would be fully as convenient and not so liable to accidents due to the slipping off of the rope brake, or the prevention of accidents by raising the weight attached to the rope brake to a dangerous extent. I should fully agree with the remarks of Dr. Thurston on this point.

I would also agree with the discussion as outlined by Mr. F. H. Ball under the head of "Ratio of Expansion," section xx., that but one ratio should be use, and that the "Commercial."

The same remarks apply to diagram factors.

In the first place, I believe very strongly in the simplification of reports and, as far as possible, the elimination of alternate methods of describing a result, and that, therefore, we, as a Society, should adopt that form which more nearly complies with actual practice.

Further, I do not see the use of an "ideal" unless such "ideal" can be one that is "absolute," and as this is practically impossible, if it is decided to have the dual standard, I would agree with Mr. James B. Stanwood that the term "ideal" should be changed to "conventional," reiterating, as before, that this "ideal" or "conventional" ratio represents something which is both meaningless and useless, and liable to create confusion and contention between possible opposing parties.

I have also been an advocate of the printing of the items describing the more important data in a larger or fuller face type than the rest of the report, so that the business man who is short of time and wishes merely to get at the ultimate object of the test can turn at once to the items which state the economical result, thus more readily catching the eye, that is, referring to Table No. 1, I would print items No. 106 and No. 107 in full-face type.

I would also strongly advocate the publication by the Society of report blanks stating that the blank is the form advised by the American Society of Mechanical Engineers, and selling these blanks to the members at a slight advance over their cost.

These two latter items may seem rather trivial, but it is the belief of the writer that they would lend considerable weight to such reports and at the same time bring the work of the Society more prominently before the business public.

Mr. R. S. Hale.—The Committee has done an admirable piece of work for which we all owe them hearty thanks.

If anything they have done too much, and too good work, and have given us a code which is unwieldy for ordinary testing, and have included so many different standards and definitions that it will require far more labor to write the report of an engine test than to make it, and more labor to read the report than to write. I should have preferred, for instance, either to leave out the various parts referring to the hyperbolic curve as a standard for the expansion-diagram, or else to recognize more clearly that this curve has no real basis in the laws which govern the expansion of steam.

It would also have been simpler to adopt the English standard for engine testing pure and simple (omitting all question of the auxiliaries), and then to have adopted a code for a "plant" test to include auxiliaries boilers and all parts of the plant.

Paragraphs 2 and 3 provide for charging the engine with all steam used by auxiliaries, and for not crediting the engine with any power developed by these auxiliaries. Of course, the auxiliary question is a troublesome one, but it should be clearly understood that this method puts a premium on driving auxiliaries from the main engine, as, for example, by shafting, or electrical means. Further, it may give trouble in many cases; for instance, what would be the allowance in case the feed water or condenser water is supplied under pressure from the city mains? Such an arrangement would not make the steam engine any more efficient.

As to paragraph 8, I think it is very ill advised. There are to-day very few steam engines which do not have a much larger reserve of capacity than would be called for by this definition, and if engine sellers should adopt any such rule as this in rating engines it would involve revising the rating of nearly every engine on the market.

Would it not be far better to give each engine two ratings, a rating for best economy, and a rating for maximum capacity, than to attempt to state a definite ratio between the two? Sometimes an engine is designed to give its best results, all things considered, at its maximum power. Such an engine might be well designed for the particular work it was to do, and yet our engine code would condemn it as not having 25 per cent. excess capacity. Sometimes an engine is designed to give the best results at a very small fraction of the work it could do if pushed to the limit; *i.e.*, a 100 horse-power engine might be capable of doing 250 horse-power on a pinch. The engine code could then allow this to be called a 200 horse-power engine which would be double its proper rating. It would be much simpler and better to either omit the paragraph altogether, or to ask that both the economic rating and the maximum rating should be given. The latter would be in accordance with present good practice. The definition proposed by the Committee is, I venture to say, not according to the best practice of to-day in rating engines.

In regard to units, I have never been able to see why the unit of evaporation (966 British thermal units) was not as useful and convenient a unit in engine testing as it is in boiler testing. If instead of British thermal units per horse-power per hour or pe- minute we should express the engine performance in units of evaporation per horse-power per hour, we should then be able to translate water per horse-power per hour back into coal per horse-power per hour with great ease, the moment the boiler performance is stated.

Section v. (d). *Water meter testing.*—I prefer when possible to weigh a known quantity of water, taking corresponding meter readings. The graduations on most meter dials are not very accurate, and if the meter reading is taken for a given quantity of water, there is less chance of error than if the meter is shut off at a given point and the water then weighed.

Section vi. *Leakage tests.*—Note should be made of the risk that the density of the water in the gauge glass connections or in the boilers may change unless care is taken. For instance, in a plant with six boilers, if only one or two are kept working lightly the steam pressure may be maintained while the others may be cooling down, so that the water in them becomes much more dense and apparently goes off as leakage.

Mr. Charles H. Manning.—Section vi. "The Leakage of Pistons," etc. In my opinion the only way of arriving at any reliable knowledge of the condition of the piston as to tightness is, upon stopping the engine after a regular run, to take off one cylinder head, block the ports or detach the valves at that end and then put the engine up to speed, and you will find that where, by the Committee's method, the piston might show a considerable leak, when running it is almost absolutely tight. The valve chests of Corliss engines when heated up distort the cylinder, and pistons will frequently show leaks when near the end of stroke, though they are tight during 90 degrees of stroke.

Mr. A. K. Mansfield.—Referring to section i., to the effect that the specific object of the test should first be ascertained, it is sometimes the case that the economy of the whole steam plant is to be determined, while it often occurs that the economy and capacity of the engine alone are the objects to be ascertained.

The latter case is the only one I have specially in mind, that being of most usual interest to the engine builder.

In planning an engine to meet given conditions, first considerations are under what pressure of steam the engine will be operated and against what back pressure. In other words, in laying out imaginary cards to plan the distribution of steam and to consider the economy with which the steam may be used, from which consideration the guarantees of the builder, both as to capacity and economy are made, an important item is the pressure of the steam, which is delivered to the engine and therein expanded (for the

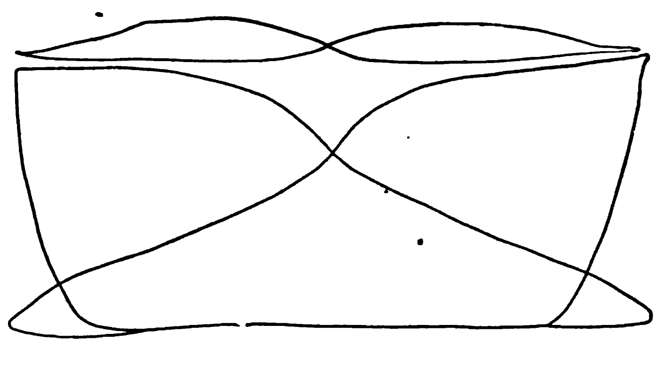


FIG. 138.

higher this pressure the less the amount of steam used per horse-power per hour), while another important item is the back pressure acting on the engine (for the *lower* this pressure the less the amount of steam used per horse-power per hour).

In making contracts for engines there is much confusion relative to these items, which produces controversy and sometimes leads to litigation, owing to the use of uncertain phrases in the contracts some of which I find in these rules for conducting tests, but without suitable definition. The phrases referred to in the rules are "boiler-pressure," "pressure at throttle," and "initial pressure," and the question I wish to discuss is which of these quantities is of interest to the engine builder, and how is it to be determined and defined.

As to the term "boiler pressure" the pressure at the engine is rarely the same as that at the boiler; moreover the pressure in the engine is commonly measured with an engine indicator, while that at the boiler is commonly taken from the reading of a steam gauge, an instrument which may not be classed with an indicator for reliable determinations of pressure. Might it not be well, therefore, to specify that the boiler pressure should be determined by an indicator if it is desirable to know the exact boiler-pressure at the time of a test.

The term "throttle pressure" is an exceedingly uncertain quantity, as has been pointed out by Mr. Ball. If a steam gauge be applied at or near the throttle, and its cock be opened wide, its needle will usually fluctuate violently when the engine is in opera-

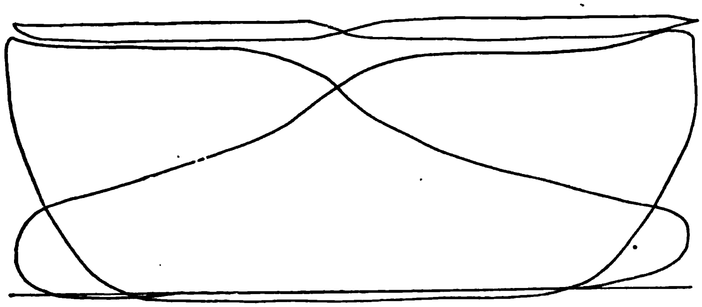


FIG. 139.

tion. If the needle be quieted by nearly closing the cock, the reading of the gauge is made totally unreliable thereby; therefore, we very much need a definition as to what is meant by "throttle pressure," if the term is to be continued.

The term "initial pressure" is probably intended to refer to the actual pressure realized in the cylinder during admission, but this pressure often falls during admission, which may be due to faults of the engine, or may be due to faulty installation of the steam-pipe between engine and boiler, or to a throttle separator, or to the fact that another engine is taking steam from the same header.

Figs. 138–140 represent actual indicator cards from cylinder and throttle, which illustrate this matter. It will be seen that neither "throttle pressure" nor "initial pressure" can be readily determined from them without some agreed-upon definition as to what is meant by the terms. Would not this be a good time and place to make an effort to arrive at such a definition? It will be clear that the throttle cards represent in each of these cases the insufficiency of the steam-pipe to deliver steam at boiler-pressure to the cylinder during admission. Therefore, these cards may commonly be used to determine the efficiency of the steam pipe. They also indicate in conjunction with the cylinder cards the efficiency of the port areas and passages, for the distance between the lower line of the throttle card and the admission line of the cylinder card represents loss of pressure between throttle and cylinder.

For the purpose of the builder of the engine, who seeks to make it economical in the use of steam of a given pressure, "initial pressure" may clearly be considered to be the original pressure

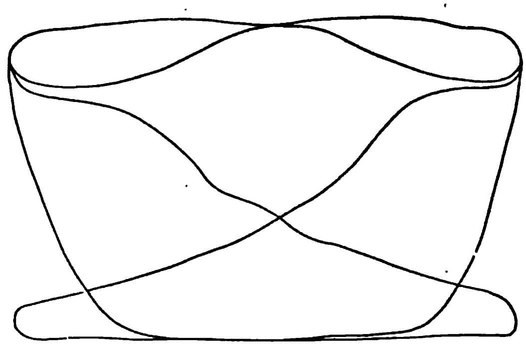


FIG. 140.

of the steam which is expanded in the engine after cutting off—assuming that we are considering an expansion engine.

This pressure might well be measured at the point where cut-off appears to begin, a point which may be determined with reasonable accuracy. But the buyer of the engine, who agrees to deliver steam to the engine at a prearranged pressure, might object that the difference between throttle card pressure and cylinder pressure at the point named shows faulty design of the engine, which point might be well taken.

It therefore appears, after considering both points of view, that "initial pressure," or throttle pressure," or whatever term may be used to define the pressure actually delivered to the engine, may be defined to be *the pressure measured at the lowest part of the throttle card.*

Relative to the back pressure acting on the engine, it is customary in contracts to state either that the engine is to be run non-condensing or that a certain vacuum (in inches of mercury column) will be provided by the purchaser. In the former case the builder assumes that the back pressure will be that of the atmosphere, but sometimes owing to defective installation of exhaust pipe, this pressure becomes several pounds higher than the atmosphere.

In case of condensing engines defective piping between condenser and engine often imposes unnecessary back pressure on the engine.

In both of these cases exhaust-pipe cards taken from a point close to the engine will reveal whatever the fault is in the engine passages, or in the piping, or in what degree it is chargeable to each.

Prof. H. W. Spangler.—This report is such an admirable one that I hesitate to comment at all on some of the minor details. There are a few points, however, to which I should like to call your attention.

More emphasis should be placed on the statement made at the end of paragraph 1 that "The heat unit expression of economy does not in itself show whether the engine is working to its best advantage any more than the expression of the steam consumption," and the report calls attention to the influence of pressure. etc. This has been largely overlooked in the past, and, in the steam engine particularly, has been the source of some confusion. To most engineers the bald statement that an engine using 12 pounds of steam is more efficient than one using 14, or the statement that a pumping engine developing a duty of 125 million foot pounds is more efficient than one developing 115 million is simply a truism. In many cases the relative position of the two engines would be reversed by running them at the same pressure. In other words, the temperature at which the heat is supplied is a large factor in determining the efficiency of an engine, and it is unfortunate that no convenient basis for the exact comparison of engines is available.

That this may be quite an important factor can be seen when it is realized that heat at 150 pounds pressure is worth about 7 per cent. more than the same quantity of heat at 140 pounds if used in the same steam engine.

Referring to paragraph 2, it seems to me that the proper title of the process therein described would be Standardizing Tests of Power Plants. As, for instance, a pumping station has four engines and sixteen boilers. If one engine is tested with eight boilers, the general efficiency of the entire plant will probably be higher than if one is tested with three or four boilers, because of the less rate at which the boilers are worked. If the regular station feed pump is used, the steam used by a pump much too large for the engine supply is charged against the engine, and part of the exhaust is probably wasted, which would not be the case in usual operations. I believe that a distinct separation should always be made between the machine using the steam and the one making it, and between the machine making the gas and the engine using it.

I want to protest against the combination of cards from compound and triple expansion engines for any purpose whatever. It means a lot of work without any return. All that can be determined from such a combined diagram can be determined in half the time from the separate cards—except one thing, and that is, we cannot see what the cards look like when put together.

In section xx. (c) the statement is made that "it is a diagram from which the pressure of the steam at any point in the stroke of either cylinder, and the volume of that steam can be measured from one diagram, etc.

Referring to figure 124, I would like to know what is the volume of the steam after the low-pressure cylinder has moved to .15 its stroke? If the report means the volume of the steam in that cylinder at that time, the combined card is no better than the separate ones, if it means the volume at that instant of the steam which originally entered the high-pressure cylinder, my question cannot be answered from the combined diagram.

You cannot tell by looking at any of the figures what the ideal diagram factor might be, and there is no doubt but that it can best be determined by calculation, as shown in paragraph xx. (f). The effect of such a diagram is to extort the figure so much, especially the high-pressure card, that it becomes meaningless. It is quite as easy to draw the dotted lines on the original card and to measure the area there by a planimeter as to redraw the whole thing and then measure it. If the purpose of drawing the combined diagram is to determine the diagram factor, I am sure that it can more easily be done from the original cards. If it is to determine how near the expansion curve comes to a rectangular hyperbola, *and of course no other lines on the combined diagram mean anything*, only draw the parts between cut off and release, or draw the hyperbolas on the original cards.

Section xx. (g)—The expression "total losses of steam in a cylinder" seems to me unfortunate. It was brought home to me by a statement made by an engineer just a few days ago that a particular set of tests showed that "for each pound of steam used in the cylinder an additional pound disappeared—was lost—he did not know where it went," etc., and the report means, if anything, the "increase in the amount of steam required" as compared with the assumed ideal performance, etc.

Mr. J. B. Stanwood.—The Committee appointed to codify and standardize the methods of making engine tests is to be congratulated on the thorough manner in which it has done its work; such an elaborate and exhaustive treatment of the subject is bound to contribute to the scientific development of engine construction and performance. To two points I should like to call attention, first: to what seems to me to be a superfluous special construction of combined diagram for the Woolf Engines; and, second: to a lack of accuracy in connection with the so-called Ideal Diagram Factor.

The Woolf Combined Diagram.

In the construction of a Combined Diagram, the Committee states that it is a hypothetical figure "from which the pressure of steam at any point in the stroke of either cylinder and the volume of that steam can be measured . . . *in the same manner* that it can be measured in the case of a single cylinder engine from the actual indicator diagram."

Now on a single-cylinder engine diagram it is impossible to measure the volume of expanding steam between admission and cut-off. The same statement is true of the Combined Diagram for Receiver Engines, both for the high and low-pressure diagrams. It is also true that diagrams from the Woolf engine can be thrown into the same general form of Combined Diagram as the diagrams from a Receiver Engine; such a diagram will also yield information on all points, as if taken from a simple indicator diagram.

Why then complicate a necessarily long report by a special construction of a special case in order to secure only one condition not considered important in any of the other cases, to wit: the determination of the volume of expanding steam between admission and cut-off of the low-pressure cylinder, a feature which this construction affords? Why not let one diagram cover all cases, as it will yield similar results in all of them?

The Ideal Diagram Factor.

A collection of different diagram factors, which are the expressions of the relation of an obtainable mean effective pressure to a theoretical mean effective pressure, the assumed expansion line being taken with $pv = constant$, and the limits being the throttle pressure and certain standard back pressures, is valuable to the engine designer as affording a quick and easy method of estimating beforehand probable obtainable mean effective pressures for engines of different types under different conditions. A collection of such data by means of standard tests will contribute to this end, and is to be commended.

But when it comes to employing a diagram factor of this character in order to point out the value of different losses, or in holding up a theoretical diagram based on this $pv = constant$ expansion line as an "Ideal" to be striven for, is not the Committee making a statement which is misleading and inaccurate, and which will tend to prevent young or inexperienced engineers and designers from obtaining correct ideas on the subject?

Professor Thurston, in his remarks at Milwaukee on the work of the Committee, says that he thinks "it should be *distinctly understood* that while in a single cylinder the expansion line may be assumed, usually without serious error, to be the equilateral hyperbola, this is not the case for very high ratios of expansion, or for the multiple-cylinder engine as a rule, or where it is important to obtain exact measures."

The Committee has taken no notice of this valuable suggestion as far as I can see, but under the head of Total Losses gives a formula of 1–CF as the total consumption of steam or heat lost in an engine, where F is the Ideal Diagram Factor determined from a diagram drawn with a $pv = constant$ hyperbola. They call this theoretical diagram an assumed ideal performance.

They might as well take the relation existing between the area of a circle and its radius of 3.5 r^2 and call it an *assumed ideal relation*, and any shortage of this amount in a calculation they would consider a loss, while in reality a more nearly theoretically ideal relation would be 3.14159 r^2 and the losses would prove different.

Perhaps the Committee was deterred from using the more exact adiabatic expansion curve by the difficulty of expressing the area of an Ideal Diagram, of which it forms a part, when employing as a basis for the diagram the steam as accounted for by the indicator at high pressure cut-off. I should like to point out how, by following with slight modification, Mr. Willan's method of analyzing engine performances, a simple calculation of the area of such an Ideal Diagram can be secured (which at the same time covers such an extreme case as that presented by Mr. Frank Ball, and also satisfies Mr. Sederholm's suggestion in regard to the error of straight clearance lines, both as offered at the Milwaukee Meeting).

The method is made easy by employing Entropy Tables such as are found in some modern treatises on the Steam Engine, and is as follows:

If instead of using as the basis of the diagram, the steam at cut-off in the high-pressure cylinder as accounted for by the indicator, we take the steam as accounted for at low pressure release, the solution is simplified.

The following data are necessary:

Absolute throttle pressure = P.

Absolute low-pressure release pressure = p.

Per cent. low-pressure piston displacement evacuated by steam at $p = k$ (equivalent to C–H of Committee's report, section xx, (a)), see figure.

Obtained mean effective pressure referred to low-pressure cylinder = M.

If condensing, back pressure $p_0 = 0$.

If non-condensing, back pressure $p_0 = 14.7$ lbs.

From this data can be derived the theoretical British thermal units, which can be secured from one pound of water expanding adiabatically from P to p with p_0 back pressure, thus,

$$\text{B. T. U.} = U = D(1 + S - A) - T_1 (A - A) + \frac{p - p_0}{5.4\, w_1} \quad . \; . \; . \; (1)$$

Where T = absolute temperature of P.

T = " " " p.

$D = T - T$.

S = Entropy of steam at P.
S_1 = " " " " p.
A = " " water " P.
A_1 = " " " " p.
w = wt. cu. ft. of steam at P.
w_1 = wt. cu. ft. " " " p.

The theoretical water rate for such a diagram is, $\frac{2545}{U} = R$..(2)

The theoretical mean effective pressure for such a diagram

$$= 5.4\, w_1\, U \quad (3)$$

on the assumption that the low-pressure cylinder is full of steam at p pounds pressure; but as only k parts are full, this mean effective pressure, being reduced in that proportion, becomes 5.4 $k\, w_1\, U$; equal to the mean effective pressure of a cylinder without clearance with a terminal pressure of p pounds.

The actual diagram factor $= \frac{M}{5.4\, k\, w_1\, U}$

The total factor loss $= CF$ (of Committee Section xx, (g)) $= \frac{R}{\text{actual water rate}}$ and $1 - CF = 1 - \frac{R}{\text{actual water rate}}$.

If the actual number of adiabatic expansions is desired it is expressed thus:

$$N = \frac{w}{w_1} \times \frac{S - A_1}{S_1 - A_1}$$

The following shows the derivation of the formulae.

Assume a Rankine Cycle. Then the theoretical British thermal units derivable from 1 pound of water, between limits as given is (L being Latent Heat of steam at P)

$$U = (T - T_1)\left(1 + \frac{L}{T}\right) - T_1\left(\text{hyp. log}\,\frac{T}{T_1}\right) + \frac{p - p_0}{5.4 w_1}$$

$$\text{now } \frac{L}{T} = S - A \text{ and hyp. log}\,\frac{T}{T_1} = A - A_1 \text{ therefore}$$

$$U = D(1 + S - A) - T(A - A_1) + \frac{p\ \ p_0}{5.4 w_1} \text{ as per (1),}$$

$$\frac{1}{5.4} = \frac{144}{778}.$$

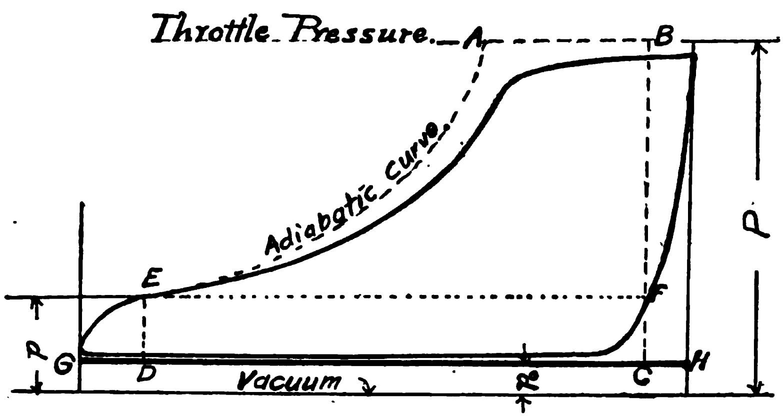


FIG. 141.—*ABCDE* = IDEAL DIAGRAM.

$$k = \frac{EF}{GH}.$$

Also, the pounds of water per horse-power hour $= R = \dfrac{2545}{U}$ where 778 = Joule's equivalent; and also $R = \dfrac{13750 w_1}{M.E.P.}$. Equating these two values of R and we have,

$$\frac{2545}{U} = \frac{13750 w_1}{M.E.P.} \text{ or M. E. P.} = 54 w_1\ U \text{ as per (3).}$$

Mr. Charles A. Hague.—The Committee deserves great commendation and credit for the testimony and evidence they submit of much careful painstaking work; but, I have an honest difference with them on a point or two. Whatever is finally adopted by the Committee and the Society, shall have my fullest support, and I will do what I can to give the results of their labors jurisdiction and force before the engine builders and buyers, and all others interested in the development of power by heat. And I know that the complete good will and earnestness in what I may say contrary to their conclusions will be understood.

It seems to me that the report lacks the best form of articulation, and in places is too general for the practical work of meeting the usual demands arising in cases where engine tests are actually wanted. To begin with, the reciprocating-piston steam engine ought to be classed by itself, and codification established for separate other forms of prime movers having heat for a source of energy, and for the reason that where heat is produced in the furnace of a boiler, and water is employed as a vehicle for the transportation of this heat to the place of work, the conditions of production and operation are too dissimilar to admit of the satisfactory grouping of all classes of heat engines. Further: the recipro-rotative steam engine occupies such an enormous percentage of the heat power field that it seems a little irregular to attempt to make a standard set of test details sufficiently elastic to cover as well, motors depending upon combustion within the cylinders of the machines themselves for the development of the working heat. Further still, the steam turbine is as yet somewhat too insignificant as a heat prime mover to justify its classification just at present with the usual type of piston and crank engine in setting up a standard of test, and partly for the reason that the easiest and most convenient means of exhibiting the energy developed, by the indicator-diagram, is not available in the turbine. To be sure brake resistance may be employed for both the usual and the turbine form of motor, and so a common ground afforded; but practically this is impossible, especially for many of the greater powers used at the present day. The turbine is too unusual, and is too often situated in a narrow field of usefulness, where its performances may be gauged by other means than foot pounds of work, to permit it to distort what should be otherwise a special. a scientific, and a practical method of determination of results.

A very practical consideration is the fact that the most important tests have been and will no doubt continue to be, principally resorted to in powers of a magnitude which excludes the types of motors depending upon combustion within the cylinders for their initial pressure. Even in considering gas engines of as high as 500 horse-power, the frequency of installation has not become of sufficient importance to justify their grouping with the usual steam engine, especially as large gas engines are mostly employed in localities where natural gas is available, although their use in moderate powers is gradually spreading; I say this as much in justice to the gas engine as for any other reason. In powers of 100 horse-power or less, aside from ascertaining desirable facts, the entire amount of fuel and steam consumed is not sufficiently important to justify an elaborate system of investigation; with good work, carried out on lines of good design, it is pretty clearly known what the results will be.

Therefore, as to this part of the report, I think it should be divided into classes, and if there is neither time nor opportunity for doing justice to all branches and classes of motors at the present time, then begin with the most valuable, the most important, and the most frequently questioned line of work in the testing field. Do that portion well and concisely; and take up as opportunity offers, other lines and classes of heat motors early in the future. The reciprocating-piston-rotative steam engine is several hundred years old, and if a codified standard is only just now being reached, surely the gas engine, the steam turbine, and other comparative novelties in the thermo-dynamic field can comfortably wait a short time, if necessary. To make this idea plainer how would it be to form classes about as follows:

1st. Reciprocating-piston-rotative steam engines.

2d. Reciprocating-piston-rotative gas engines.

3d. Reciprocating-piston-rotative engines consuming combustible fluids.

4th. Turbines, and other forms of rotary engines.

Take the classes of work up in the above stated order, and keep them entirely separate, so that each class of heat motor may be considered at its best, and its questionable points without interruption or interference by any other.

Proceeding then along the line of classes above mentioned, and taking at present the reciprocating-rotative steam engine as a rather complete line of itself requiring a great share of attention, I note an incipient confusion in the use of the term "object of the test." That is to say; the term "object" seems to be used as representing the determination of economy; and also used as representing something to be ascertained with regard to a contract. The word is qualified in its meaning it is true; in one place being used in a broad sense, and in the other specifically.

Now, it seems to me that the "object" of an engine test is the all important element in the case, dominating and influencing all matters and details of procedure throughout; and, therefore, to my view there should be one object and one only; all else taking secondary relations thereto. And, as engines are made to sell to some one, and to do work for some one, it strikes me that the most important object in forming rules for testing a steam engine, is to ascertain whether or not it meets the requirements of the contract under which it is built and erected; and so the codified and standardized methods of making engine tests should be largely based upon the matter of how near together the requirements of the contract and the performance of the engine are actually brought by the efforts of the engine builder. If this is taken as the standard and fully covered, it will likely be found that nearly, if not quite all other considerations may be met under a system of procedure based as clearly and as exclusively as possible upon the contract idea. Of course the contract idea is considered as is plainly shown, but I think that much more dominant conception in that line would improve the matter.

The science and art of mechanical engineering is largely made up of producing and selling machinery for useful purposes, and if it were not for the sale and use of the machinery, the mechanical engineer would have very little to do. This being considered as so, the importance of catering somewhat strongly to the satisfaction of the contract, and ascertaining how fully it may be met by the machinery produced for the purpose, will appear. It must be admitted, of course, that engines are tested for other reasons, but the point I endeavor to make is, that in establishing a method, nearly all points will be covered by making contract requirements the all important and controlling idea, and most other details and questions secondary at best. The economy of steam, although of very great and almost paramount importance, is only one after all of several important items; there are as well, economy, reliability in the matter of required power, prompt adjustibility in the line of variable demands for power, weight, strength, durability, and mechanical arrangement and design. Under some circumstances, 10 per cent. less repairs might represent a greater desideratum than 15 per cent. steam economy. In the case of the electric railroad prime mover, some other things than steam economy hold the practice away from triple and higher expansions and keep pretty close, so far at least, to double expansion. By the way, why do we give the proper term to other expansions, and call one of them "compound."

I am not particularly hide-bound in the matter of the unit for expressions of steam economy or consumption for steam engines, but reasons of conciseness cause me to lean very strongly towards the making of such expressions in pounds of dry saturated steam; and I never have believed sufficiently in the heat unit basis to make a standard of it. I bow to the powers that be, or may be, but personally I do not agree with them. Of course, the engine builder is very intensely interested in the various details which go for the production of a machine which will develop the greatest number of foot pounds of work per stated weight of proper steam; but after all that is his affair, and if he fails to pay sufficient attention to its importance he will lose his customers. For years I have advocated the separation of the production of the steam from its use in an engine, and with modern appliances the engine need not be charged with other than dry saturated steam, or at least its credits can be arranged so as to enable the correct expression being made which will exhibit the facts. A steam engine is built to use steam and produce power; and whatever may be its internal arrangements affecting the damaging, wastage or loss of steam unnecessarily, such signs of incompetency as may be shown to exist proclaim, by the excessive consumption of steam, that the best lines of thought upon the subject are not being followed by the builder.

Therefore, I am inclined to take issue with the Committee under paragraph 1, upon the selection of the unit of determination in expressing the results of tests of steam engines, and in doing so, I take my argument from the statement of the Committee itself. They take the position that heat produced in the furnace of a boiler is to be viewed in the same light as heat produced by combustion directly within an engine itself, specifically designed and arranged for combustion. This idea ignores several facts with which the Committee is perfectly familiar, viz.: That combustion in a boiler furnace involves: (a) the chemical operation called combustion, which of itself is too far removed from the operation of the steam engine scientifically, and calls for the consideration of too many things entirely foreign to the engine and its work. Further than this: (b) after we have passed by the special and exclusive considerations pertaining to combustion, which might apply with equal force to a pottery kiln or any other form of economical furnace for any purpose whatever; we are met by another intervening operation before the heat becomes available by use in the "heat engine," which, perhaps, might properly be called strictly a "vapor engine." This second item, is the actual fluid composed of a mechanical mixture of heat and water which makes the engine available for useful work, and the design and arrangement of the steam generator bears to a very important extent upon the quality and quantity of the mixture obtained; so by the time we have reached the throttle valve, where the engine really begins, we have run the gauntlet of several sets of conditions over which the engine exercises no control, and some of the losses involving the expenditure of heat have already been active to a very considerable extent.

The Committee states that, "Fuels are proverbially of uncertain quality, whatever their class." Well, so they are, and I will adopt that expression for my side of the case, and not charge the engine with such foreign items. It is also stated that, "Steam boilers are of variable efficiency, even with fuel of identical quality." Well, so they are, and I also adopt that statement for my argument, and ask, why on earth should a steam engine be held responsible? Of course, it is not intended to hold the engine responsible; but, then why drag in extraneous considerations; and why not take the steam offered from whatever source, strike a balance on quality, charging and crediting the engine to correspond, and balance up the work done by the machine.

The Committee also state that, "In a steam engine, the weight of steam consumed represents no exact measurement of efficiency, for the reason that the true thermal economy is somewhat affected among other things by the disposition of the rejected heat of the engine." Now, what is meant by the "true thermal economy?" The expression certainly will have to be strictly and closely defined before expressions of results can be made intelligible. I believe, when we want to be exact, that a steam engine ought not to receive credit from the operation of all sorts of extraneous fixtures. Any preheating, reheating, feed water heating, or superheating, by means of boiler uptakes, etc., should be eliminated from the calculations concerning the engine itself for the simple reason, that outside influences do not belong to the prime-mover. The consideration of the above mentioned "extras" belong to "plant testing," and not to engine testing per se.

A code of standard method should be arranged to take in all kinds of steam engines not differing unreasonably from well recognized practice, and arranged so that any statement of extraordinary details or conditions can be included in the expression of results. After the steam has worked in the jackets, cylinders, and heaters or reheaters within the engine itself up to the point affecting the energy produced, and transformed into mechanical energy against the crank pin, all elements affecting the economical return of heat to the boilers by utilizing even normal and natural wastes, should, I think, be eliminated from the credit side of the engine account. Of course, scientific and clever designing and manufacturing engineers, will and can and do produce a combination of plan details and economies which will bring them their share of business when their talents become known to power users; but when a body which really appears as one of professional men, proposes to set up a code of standards, such a code should be fairly applicable and to a discriminating extent, so that the "true thermal economy," and also the true results properly stated, will be easily grasped.

In paragraph 2 the real point is stated: "The heat consumption of a steam engine required for the standard test is ascertained by measuring the quantity of steam consumed by the plant, calculating the total heat of evaporation of the entire quantity, and credit this total with that portion of the heat rejected by the engine, which is utilized and returned to the boiler." And this is right where I take issue with the Committee, inasmuch as I believe that they are trespassing upon unscientific grounds in taking such a position. The engine of itself and as produced by the engine builder has nothing whatever to do with what becomes of the rejected heat. As to auxiliaries, the engine should only be responsible for the air and jacket pumps, as those pumps are the only ones absolutely necessary for its proper operation. As to circulating pumps, wherever the situation dictates the use of circulating pumps, there are advantages which enable a surface condensing apparatus to pay its own way; and the credit for which the engine should not have, and with the operation of which the engine should not be charged; the engine itself must in some manner remove the vapor and air from the condenser proper, and as it receives a benefit in the removal of the initial atmosphere, it must be charged with the work of such removal, but the horse-power represented by the air-pump, whether merged in that of the engine directly, or produced independently, should be credited to the main engine as it is a part, although not a useful part, of the work done. For the jacket pumps of course the main engine must be held responsible, as the economy of the steam consumption within the cylinders is directly affected by the use of the jackets, and their power consumed should be a credit. As to feed pumps, I do not consider it fair at all to charge the main engine with the steam used by independent feed pumps. If you hold the engine responsible at all for feed pump work, it seems to me that the limit is reached when you charge against the engine the power represented by the pumping of the feed water into the boilers, just as though the feed pump were attached to the main engine. That is to say, before the comparison is made between the power given out by the engine and the unit of consumption deduct from the indicated power of the main engine the power represented by the pounds of feed water multiplied by the feet head represented by the boiler pressure. In case of an attached feed pump or pumps, this would, of course, be unnecessary.

The statement in this paragraph, that the engine is finally benefited by the heat which auxiliaries return to the boilers, is not correct, for the simple reason that the benefit accrues to the boilers, and although it saves fuel used in the operation of combustion and saves heat during the operation of absorption through the heating surfaces, the amount of steam consumed by the engine is not necessarily affected whether the water goes into the boilers at the temperature of melting ice, or at the temperature due to the working pressure. The steam passing through the main steam pipe, supplying the jackets, the steam cylinders, and if necessary the air and jacket pumps, is the steam consumed by the engine proper; and although the boilers are welcome to any rejected heat resulting from the operation, the steam consumed by the engine is the steam passing into it while it is doing work, and the economy of the engine depends upon the relations between the steam expansion, the jacket heat, the temperature and condition of the final exhaust, the clearances, and other details. Therefore, it seems to me that your Committee is really dealing with "plant testing" and not "engine testing."

Of course, it is possible enough to consider the steam engine as a heat engine in the strict sense, but it seems to me that such a course is not parallel with the present report, and not consistent with the use of the same term applied to what would appear as "combustion" engines. To be strictly scientific, when using the term "heat engines" all of the heat rejected by the steam engine, whether returned to the boilers or not, should be deducted from the amount of heat received in the steam. This brings us back to the expression of a heat unit test of a plant, instead of a heat unit test of an engine; and would give a steam unit test of the engine, and a heat unit test of the plant.

The last portion of paragraph 2 shows the wide difference between a steam engine and a combustion engine; and the only way to really bring all engines into the same fold upon the heat unit basis is to ascertain the heat units of the coal burned under the boilers, exactly as you ascertain the heat units of the oil or gas fuel for the combustion engine; and then compare the heat units possible to develop by the combustion of the selected fuel, with the indicated power of the engine. The mere fact of burning the fuel under or in a boiler instead of in a cylinder, is only a matter of detail after all, if you are going to charge up the heat units produced, and credit the power developed.

In paragraph 3 the confinement of the indicated power to the net power of the main working cylinders I have already touched upon, and can not but consider such a procedure as inconsistent with what we are searching for.

Paragraph 4 opens up the entire question as to whether a concise and strictly steam test should be made of a steam engine, or whether the element largely embodying plant testing should be adopted. I have always been in favor of a strictly steam test as being the more scientific of the two methods, and as being the more useful to the steam engine builder, the heat unit test offering temptations, or at least opportunities, for builders in competition to throw some of the burden of the ultimate economy to which a power user is entitled, regardless of the engine, upon something besides the engine power. Engine builders, of course, have plenty of pride and ambition according to their lights, but some of them do not seem to have so many or so bright lights as others.

Paragraph 5 it seems to me is better applicable where estimates for requirements are wanted than for engine tests, or for a standard of efficiency where comparisons are desirable in adjusting damages or shortages under contracts.

Paragraph 6 suggests the same remarks concerning which method should be primary and which one should be secondary. I think, that the dry saturated steam is the proper one for steam engines, with air pumps and jacket pumps reckoned in the gross power, and with the friction of the main engine, and the power of the prime auxiliaries, considered as the tare or the difference between the useful efficiency and 100 per cent. Then count as subsidiary all heat unit tests, which depend for their expressions upon the efficiencies of other elements of the plant than the engine proper; that is to say, I consider the heating of feed water by rejected heat, the quality and manipulation of coal, and other details of general operation of a plant as certainly embodying subsidiary efficiency.

In the second portion of paragraph 6 which I heartily endorse, occurs a statement which encourages me in the idea that the contract requirements furnish the principal object for the test, and whenever and wherever such an object is completely met, all desired scientific, practical and constructive knowledge will be easily found at hand, for the reason that the use of the engine is its cause for existence, and its use consistent with its purposes and surroundings can not be well overtopped by other considerations; but it will be unwise to endeavor to give a method of such breadth that it will be too thin in spots, or else we may not secure a good fit at some particular points desirable.

Paragraph 7 mentions an important item to steam engine owners, and that is the commercial test which smacks a little of the proposed standard method; but combination testing needs articulation so that the actual bearings may be perceived and set forth. Of course, when a plant is in place and owned by somebdy, there is generally a strong feeling that it must be gotten along with somehow, but the mere statement of pounds of coal per horsepower and per hour, cannot reveal the virtues and failings of the plant as a whole; a good engine and a bad boiler show the same results as a good boiler and a bad engine in a combination test.

The recommendation in paragraph 8 is a proper one in my opinion, and will be found in the long run to be on the side of the most constant economy.

I will briefly go over the "Rules for Conducting Steam Engine Tests. Code of 1902."

I. I follow the text of this rule very closely in practice, and it will be found advantageous to be extremely specific, even going so far as to carefully digest the reasons and conditions which bring about a test, and commit to paper a consistent line of action which shall guide throughout the test. Especially in connection with the satisfaction of a contract, it is particularly necessary to have the line of action and determinations fully understood and agreed upon beforehand.

II. This rule is plain enough as far as it goes, but sometimes, in case of a disagreement between a seller and a buyer of a steam engine newly put in, an expert is called in to determine merits of the case just as it exists and the test has to be made "red-handed," so to speak. Of course, there are ways to meet such conditions which must be left mostly to the judgment and good sense of the referee.

The detailing of methods of ascertaining if the pistons and valves leak, are probably as explicit as can and need be; but much, especially as to the determination of the quantity of leakage, must be left to the person conducting the test.

III. A part of this rule deals with the measurement of clearances or waste room, and this item is probably as troublesome as any to be met with in any of the operations. The pouring of water into waste spaces is a rather doubtful experiment, and oftener unsatisfactory than otherwise in determining the cubical contents. I would much prefer the calculation of the drawings, and believe the latter course to be the most trustworthy, in fact far more accurate than depending upon valves and pistons which are operated in hot steam, as to their possibilities for holding practically cold water, sufficiently safe to keep the determinations within reasonable accuracy. In any engine sufficiently important to demand a close decision, there will no doubt be blueprints or drawings to figure from, which, with the facilities for checking by some measurements which may be taken from the engine itself, will afford the information desired.

IV. With reference to coal, the remarks are well made, and should be followed consistently where possible. I have known of disputes over that very item of coal where contractors, in claiming the "best coal to be obtained in the market," demanded the use of coal which would have to be brought from afar, and not usually found in the "local" market. The standards of the A. S. M. E. *Transactions* should be mentioned in contracts wherever possible, and it would be well for members of the Society to make a practice of rendering decisions upon this basis, especially with reference to locality, whenever a doubt in a contract gives them an opportunity to do so.

V. The importance of calibration of instruments goes without saying as to guages, thermometers, indicator springs, and the like. I do not rely very much on water meters for determining quantity of water fed to boilers; there are too many variations with temperature, etc. I know that there are many well-meaning advocates of meters, interested, disinterested and otherwise; some not wanting to take the trouble of tank weighing or measuring; but, when I want to know the facts, I do not want to be exposed to the percentage of errors possible in meters.

VI. Concerning leakages the remarks are appropriate and to the point, but I fancy that there are as many anxieties about a surface condenser, its connections and possibilities, as concerning steam pipes and other initial chances for untallied losses. Of course absolute assurance must be had as to tightness or absence of leakiness of all pipes and connections which would vitiate the conclusions. Blanking off pipes is sometimes necessary, although open outlet valves on a pipe supposed to be shut off will often either give the desired assurance or dictate blanking. The Committee certainly gives evidence of fully appreciating the value and necessity of certainty that no unknown items of this kind exist; all precautions in every other function of a test would come to naught in the presence of in or out leakage.

VII. Regarding time of duration of tests, I follow the rule wherever possible of twelve hours. for a steam test and eighteen hours for a coal test; and unless conditions exist which cannot by any means be modified—which is really seldom—the above mentioned times will be found to be quite satisfactory. In a factory or shop where the reguałr units of time are ten hours for a day's work, a steam test and even a coal test may be made to do. I note that the committee admits five hours, which although rather short even for a feed water test can be made to do in appropriate hands and under favorable conditions; for any kind of a fire test I should not be satisfied with five hours, as the manipulation of a "fat fire" at commencement and a "lean fire" at the finish would alter the facts by considerable percentages.

VIII. The starting and stopping of a test is strictly orthodox as far as I can perceive, at least I fully agree with the plan, and generally follow pretty closely the lines laid down in the report. The novice who is a stickler for the exact scratch on even hours for start and finish, will soon be taught by experience that it does not matter how many odd minutes there may be in the run, as the beautiful laws of averages and decimals will bring a perfect balance; the main thing is to know when the test really commences, and when the conditions necessary to be identical at start and finish are really so. The scrutinizing of fires for condition at start and finish, and the cleaning and putting into condition of the fires, requires mature judgment and should be conducted by more than one person where possible. The conditions are well laid down in the rules and need little comment.

IX. The measurement of the results by heat units, I never did take to kindly and I have already commented sufficiently, or too much, upon this point. In the first and second paragraphs the uncertainties to be met with are outlined, and to my mind offer arguments against the system. I hold that feed pumps and pipes, heaters, separators, and all other extraneous elements are not part of a steam engine or its work, and that the weight of steam delivered at the throttle and brought to a basis of " dry saturation " is all that is necessary, and all that the engine is responsible for or chargeable with. The engine takes the steam and turns out what dynamic energy it can with the weight supplied; using power to overcome its own friction and the resistance of the appliances for maintaining the vacuum which gives the help of the " bottom atmosphere;" also whatever work is necessary for keeping the steam jackets and the like, in proper condition. Beyond this a steam engine cannot reach, and as the weight and quality of the steam must be ascertained even for the heat unit basis, I see no reason why the steam test should not be standard, and the heat units grouped and manipulated by outside elements, come in as subsidiary.

In the third paragraph in discussing the steam used for auxiliaries, the Committee incidentally strengthens the idea that a contract is generally the basis and object of a test.

X. Remarks upon measurements of feed water or steam consumption are to the point and cover the ground in a satisfactory manner, and the Committee give very concise and useful information concerning the weighing and manipulation of the feed water.

XI. This section seems to be sufficiently full and comprehensive to answer all purposes, with the understanding, of course, that extraordinary conditions are to be treated as the situation best dictates.

XII. The remarks on coal measurements and commercial tests seem to be comprehensive, and when these rules are adopted as I presume they will be, in the present form, all members of the Society should make it a point to follow, as far as possible, the subject of coal and coal tests, as laid down in the final report, as the matter of kind and mine of coal, method of scrutinizing and gauging the fires, and kindred items, have often been in dispute where contractors have been looking out sharply for their interests. A persistent practice of following a set of rules endorsed by the A. S. M. E. will after a while make them not only technically standard, but, to a great extent, legally so, and thus ward off many disagreeable disputes.

XIII. Remarks on indicators are very good and speak of experience upon the part of the Committee. As to the number and time of taking the diagrams, I fully agree that exactness in coincident cards is not necessary, and in nearly all cases will make no difference in the general results. I believe in taking a good many cards and have tried taking cards all day as fast as possible, moving from one indicator to the other regardless of coincidence for any one cylinder or other cylinders, and found that the average will make up quite as well as the most punctilious regard to isochronal efforts. I have often used the repeating method of taking diagrams, that is, taking a number on one card, and have a case in view where fifty diagrams made no broader line than a rather dull pencil would have accomplished in going over once; I cleaned up the indicator piston and spring, and made sure that perfect freedom of motion of the indicator existed, as such steadiness of motion in the engine did not seem probable. But the evidence was not to be doubted, several trials demonstrating the steadiness of revolution as being well nigh perfect; the load was quite a large number of machine tools doing light work, so that the possible percentage of variation was very small in the changeable energy, while the power represented by the line shafting, counter shafting and tools heads was quite a large proportion of the total.

Indicator pipes are of themselves a study at times, and beyond getting the steam in and out of the indicator as quickly as the surroundings will permit, little can be said. With reference to the influence of indicator pipes longer or shorter, I have seen long pipes work both ways under different conditions; that is, with the ordinary three-way cock and pipes half the length of the cylinder the usual effect is perhaps mostly to increase the diagram; but in a case of a certain pumping engine with Corliss valves across the cylinder heads, the arrangement of the steam jackets and other details made necessary rather long indicator pipes even at each end of the cylinders, especially on the low-pressure cylinder; the result was that the sluggishness of the steam in getting out to the indicator prevented the full initial pressure being realized in the indicator, and the indicated power of the steam end of the engine was less than the power represented by the water pumped, thereby showing an apparent efficiency in the engine of about 105 per cent., which looked very much like perpetual motion. Perhaps if some form of dynamometer could be used in checking tests of mill engines some such results might occasionally be met with.

XV. With reference to brake horse-power, I have little to do with such methods of tests, as the work falling my way has been too "powerful" to admit of the use of brake determinations, although I should judge that the device illustrated would be desirable within its limits.

XVI. The remarks on quality of steam seem to cover the ground satisfactorily, and the method laid down concerning calorimeter performance seems to be unobjectionable, although some trifling variations in detail might be practised.

XVII. For ordinary work in reckoning speeds of engines, no doubt the revolution counter is so far the most practicable and best means, and its readings will permit of averaging the speed as to revolutions per minute to any extent of decimals, which answers every purpose. The variations in angular velocity evidently need some further study before standards are established, although satisfactory determinations may now be made when necessary.

XVIII. With reference to recording the data, although a log-sheet, suggested by the Committee, might not be imperative, it adds to the value of the report to present what could be a standard log-sheet or book, and which in many cases could be used in part or mostly, even if not completely.

XIX. In the great majority of cases I do not consider extreme uniformity of conditions as requisite, as the laws of average within fairly broad limits will balance errors to a remarkable extent. Still it is a good idea, and perhaps in some cases necessary; it is always well to have the ideal conditions and efforts right up to the theoretical level in the operator's mind at least, as such a mental attitude will act as a spur and hold a man up against patience-trying obstacles. If the science of mind can always be kept a little in advance of the actual practice a tendency to improve will no doubt exist.

XX. Remarks on "Heat Analysis" are well put and are sufficient in a general statement, which this paragraph must necessarily be.

The study of "combination diagrams" is very interesting, and should be carefully heeded by at least one party to a test where satisfaction of a contract is to be ascertained. The user cares nothing about the matter, but the builder needs to know why he succeeds or fails in what he undertakes, and where the path of advancement lies.

I scarcely see the importance of the "commercial cut-off" in a code of rules, although there is no objection to it. It seems to me like padding the code, so to speak. The real cut-off is probably where the curve reverses from the "choking-off" of the inrushing steam to the beginning of the actual expansion. The best effects in steam cylinders cannot be obtained without approximately correct expansion, and the final determination of good economical effects is proper evidence that the cut-off has taken place with sufficient sharpness to separate the expansion of the entire body of steam back to the boiler or receiver, from the expansion of the smaller body of steam entrapped within the cylinder by the closing of the induction valve. The diagram itself gives the only possible evidence of the point of cut-off for detaching cut-off gear, because the drop of the cut-off with vacuum pots or with weights, is practically constant, while the point in the stroke at which the suppression actually takes place with a certain point of detachment depends upon the flight of the piston during the drop.

The ratio of expansion and the diagram factor are well stated, and assist greatly in keeping the ideals of the engine builder at a respectably high level. I am inclined to the opinion, however, that such considerations are strictly to be considered among the mental tools of the expert, rather than as a part of a code of methods.

XXI. Remarks under "Standards of Efficiency" do not change my views as to placing the steam consumption basis in first place, and the remarks in fine print in section xxi. tend to show that the standard method will represent a plant test instead of an engine test. Whatever the Committee finally decides upon and the Society adopts I shall fully indorse and act upon, but impressions upon one's mind are rather automatic and sometimes difficult to subjugate, although possible to control.

XXII. and XXIII. These sections speak for themselves and do not call for any particular comment as I can see.

With reference to the rules for conducting tests of gas and oil engines, I am not particularly interested in the operation of such engines, but the ground seems to be well covered, involving as it does the matter of caloric directly used instead of employing a vehicle to transport the heat from the point of generation to that of usefulness. It is real heat unit testing, as nothing intervenes between the production and use of the heat in the same machine.

The tables giving data and results of steam engine tests are well thought out, and no doubt cover practically all that is needed in the way of a log. Occasions will of course arise needing something not foreseen by the Committee, but the value of the proposed log-sheet consists in having one which is sensible and consistent, upon which to base a test.

Mr. Charles L. Heisler.—The Committee, in referring to calorimeters under Section xvi. "Quality of Steam," writes:

"We recommend that a separator should be introduced before making a test, so as to free the steam of all moisture that it is possible to remove, the calorimeter being attached beyond the separator."

Having become interested in the subject of calorimetry, when a student in 1888, I naturally, like others, experimented and devised improvements in such apparatus, and consequently relished the perusal of the many pages of very valuable experimental data and expressions of opinions recorded by experts in the *Transactions* of the Society. From a study of the development of calorimetry, as brought out in the papers, I believe even the most casual students of the subject agree with what is in part suggested by the above quotation from the Committee's report, *i.e.*, when making a refined test, the perfect separation of all moisture from the steam just before it enters the engine is of primary importance; and since it is impossible to get a sample of the steam mixture from which can be accurately determined the percentage of moisture, the calorimeter should be used to indicate or detect any trace of moisture which may pass through the separator; in other words, its function should be to detect the slightest imperfection in the working of the separator, rather than to attempt the impossible task of accurately measuring the actual amount of moisture mixed with the steam passing to the engine.

It is apparent that when seeking accurate results, the commercial separator, although amply efficient when doing the everyday work for which it was designed, is not near enough to perfection for use in refined tests; furthermore, it is well known that a very much higher degree of refinement has been secured under less favorable conditions than those which are met in the problem before us; as shown by cream separators, which practically reach perfection in removing nearly every trace of cream from milk.

In the year of 1896, while teaching at the Pennsylvania State College, I was very much impressed with the data furnished me by a capable chemist in the agriculture department, who stated that often they find but a very slight trace of cream after separation under favorable conditions, and usually about $\frac{1}{3000}$ part of the cream remains in the skimmed milk. This certainly emphasizes the possibility of an easy solution of the separation problem, particularly when considering that equal volumes of skimmed

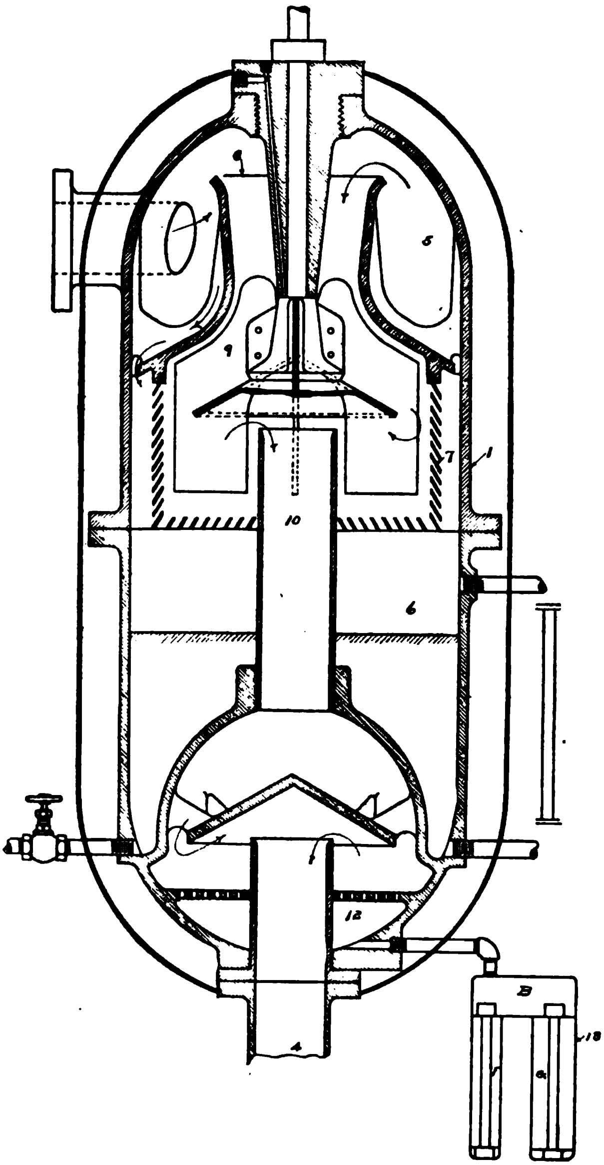


FIG. 142.—FAN SEPARATOR.

milk and cream, when weighed, are approximately as $\frac{11}{10}$; whereas moisture and dry steam give roughly at least a ratio of $\frac{1000}{1}$ in favor of perfect separation. To try the experiment promptly suggested itself and resulted in the sketching out a separator of which the device shown in Fig. 142 is a slight modification in form. The material for the apparatus was furnished by the Engineering Department of the Pennsylvania State College. The apparatus was made by two senior students and experimented with by junior students at the end of the spring session. Unfortunately, the close of the term gave time for only a sufficient number of runs to show that the apparatus readily separated even when a jet of water admitted some distance above the apparatus gave a mixture containing 50 per cent. water. The excess of water was first trapped in the upper separating chamber 5, and from there it passed back of the serrated and perforated shield 7 directly to the catch chamber 6. Only the "mist" or fine particles of moisture held in suspension passed down through the throat 8, and met the rapidly revolving fan 9 arranged directly over the exit 10. Evidently the conical centrepiece of the fan obliged every particle of steam to pass its vanes twice, as shown by the dart, so that it was reasonable to expect that it proved an effective barrier to even the slightest trace of moisture, particularly when considering that the fan may be revolving at least 5,000 revolutions per minute and upward. The fan may be driven by any suitable motor. When not in motion the apparatus acts as a commercial separator.

The first impression was that we might have considerable wire drawing and a slight amount of superheat due to the heat equivalent of work done by the fan. Gauges did not show any difference in pressure, which appears partly to be due to the suction of the upper fan vanes being greater than the resistance of the lower vanes; and because the passages through the traps or separator are large when compared with the steam-pipe area. It appears that superheating would have been desirable, since it would have been proof of the dryness of the steam, and would have been easily allowed for; however, the very small heat equivalent of the fan's work became infinitely minute as compared with the immense volume of heat passing through the apparatus, so that no superheat was detectable.

If it is desired to check or test the apparatus, and detect any trace of moisture which may have passed the fan which will naturally collect in the pocket 12, it can be quickly done without calculation by the automatic measuring separator which is detailed in Fig. 143, and consists of the usual separating trap *A* and *B*, which precipitates the moisture into the small tube *F*.

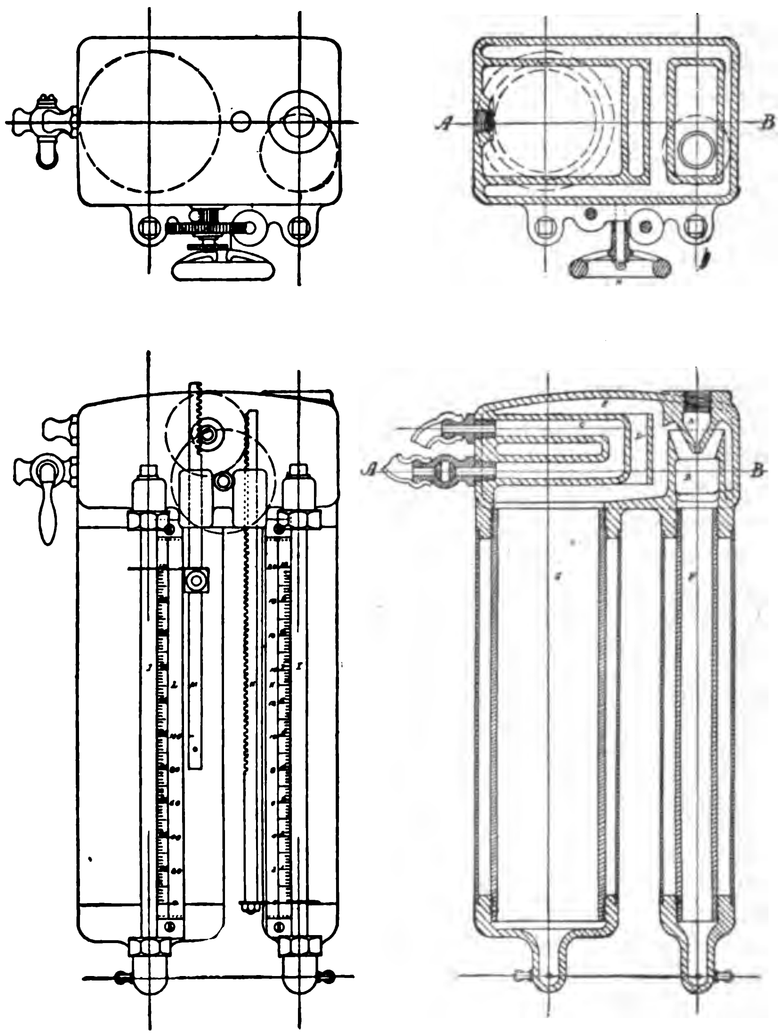


Fig. 143.

The dry steam passes to the left and comes in contact with the condensing tubes *C*, and is collected in the larger tube *G*.

To determine without calculation the percentage of moisture in the mixture trapped at 12 in the bottom of the large separator, shown in Fig. 142, it is only necessary to adjust the small pet cocks on the measuring separator, so that the liquid levels in both tubes G and F coincide with zero readings on the scales L and K. The length of these scales is divided in the same proportion as the volumes of the tubes G and F, which are as $\frac{10}{1}$. After adjusting the liquid levels at zero readings, both cocks are closed; the right-hand scale bar, or rack N, is moved upward so that the pointer, now shown at zero, follows the liquid level upward. Meantime the small gears having a ratio of $\frac{10}{1}$ cause the other pointer on bar M to move $\frac{1}{10}$ as fast downward from the 100 reading, until such time as it coincides with the liquid level in the glass of the larger tube G. The scale readings, taken when both pointers coincide with their respective levels, correspond to the relative percentage of liquids collected in the two tubes, and consequently the percentage of moisture. By clamping the gears, the result can be immediately checked by again lowering the liquid levels to zero, then closing the cocks, and without touching the apparatus noting that both liquid levels in the glasses coincide at the same instant with the scale pointers. Manifestly a throttling calorimeter will answer for the same purpose, but it is not so convenient, requiring considerable calculation.

It is not clear to me why a much better or fairer sample can be obtained from an upward flow of steam than from a downward flow, as we all well know that liquid particles adhere to the walls of an exhaust pipe whether it discharges upward or downward, the mixture arranging itself in the same manner in either case; the heavier particles find their way to the walls and out of the swifter central current because of the eddying action due to the frictional resistance and adhesion of the retaining walls. This may be due to the fact that the effect on the moisture produced by the impelling forces causing the rapid flow is very great as compared with the effect of gravity, so that the influence of the latter is practically nil with steam flowing one-half to one mile a minute, more or less. It may be, however, that the results of somebody's experiments upset such reasoning.

Mr. Wm. S. Monroe.—There are a number of things in the report of the Committee which, from my personal experience in the testing of engines, I cannot but take this opportunity to criticise. The Committee has evidently gone very exhaustively into the many methods which have been current for testing engines and the various ways of figuring their efficiences, but it seems to me that they have endeavored to harmonize these various systems rather than adopt a simple and concise method of testing which shall bring out a definite and incontrovertible standard of determining their efficiences.

The report is intended to present a method of testing an engine, and yet it includes a complete test not only of the condenser, but also of the feed pumps and boilers and to some extent of the piping as well. I am very strongly of the opinion that the engine test should stop with the engine, and that the efficiencies should be figured between the heat in the steam at the throttle and that in the steam in the exhaust pipe just outside of the low-pressure cylinder. In the large plants of to-day the condenser arrangements are so varied that they cannot be considered to form any positive portion of the engine itself. In very few plants is the air pump driven by the engine, or by an engine which is at all comparable in economy with the main engine, and in many there is one large condenser which takes the exhaust from several engines. In any case the efficiency of the main engine has nothing to do with the method of driving the auxiliaries. Consider an engine of 1,000 indicated horse-power operating on thirteen (13) pounds of steam. The air pump and circulating pump, if there is one, may be driven in several different ways. We may take three for example, as follows: (*a*) direct, (*b*) separate, (*c*) electrically. The pumps require, say 50 horse-power. In case (*a*) the pump-steam consumption will be 650 pounds per hour; (*b*) will require, say 4,000; (*c*) about 900 pounds per hour. Other things being equal, what is the efficiency of the engine under these conditions? The water consumption in the three cases is—(*a*) 13,650, (*b*) 17,000, (*c*) 13,900; or per indicated horse-power of the main engine—13.0, 17.0 and 13.9 pounds respectively. But if we drive our pumps electrically, then according to page 4 of the report we need not take their steam consumption into account at all. Could anything lead to more confusing comparisons?

In case (*b*) in actual practice the exhaust of the air pump would in all probability go to the receiver of the main engine, or to a feed-water heater, and even the "long form" of report does not to my mind adequately account for the heat that it thus given back to the plant; at least so as to credit the engine with it.

Again, engines are frequently sold on a guaranteed economy, and I have not met with a case of this kind in which the air pump was considered as entering in any way into the economy of the engine. In street railway and electric lighting work, especially, I am quite certain that the guarantee is almost invariably based on a certain condition of steam at the throttle and a certain vacuum in the exhaust pipe.

I recognize the fact that the reports, both the long and the short forms, give an opportunity to express the efficiencies of the main engine alone, but I cannot but feel that at least in the "short form" all consideration of the auxiliaries and of the boiler plant should be cut out entirely. In many of the large street railway and lighting plants which are representative of the best practice of the day, a complete test of the station would be a physical impossibility; the only complete test in such cases being in the cost sheets which show from month to month the cost per unit of output of fuel, labor, oil and sundries and repairs. It is very possible, however, in such cases to test separately the boilers, engines, condensers, pumps, heaters, and other auxiliaries, and it would be of great value to have a code for each, and we might also have a code for testing the entire plent where such a test is possible; but it seems to me it would be much more in accord with the tendencies of modern practice to make the engine code refer to the engine alone.

I would criticise especially the fact that two "short forms" are proposed by the Committee. I plead here again for simplicity, as I feel sure that the simpler the code is made the more effective it will be in practical application. After stating specifically that the weight of steam consumed is an unsatisfactory measure of performance, and that the standard of consumption for all classes of heat engines should be referred to heat units, the Committee draws up two short forms of the code, one of which ignores this recommendation entirely. The Tables numbers 2 and 3 differ mainly in that in Table 2 the weights of steam used are reduced to heat units, while in Table 3 this is omitted. Would it not be better to add to Table 3 the items relating to heat units and omit Table 2 altogether?

I have been greatly surprised to find that there is no mention anywhere in the report of that most satisfactory analysis of the steam engine, namely, the entropy-temperature diagram. Until recently, to include this diagram might have involved an amount of work which would be warranted only in a scientific investigation. But since the work of Henry A. Golding, published in England, and of Prof. Sidney A. Reeve, in this country, and especially by means of the charts devised by the latter, the preparation of the entropy diagram has become quite a simple affair, and for an adequate graphic analysis which shows at a glance the heat losses in the different parts of the stroke, the effect of clearance, contracted valve parts, superheated steam, the extent of cylinder condensation and effect of incomplete expansion, nothing yet devised can compare with this diagram.

In the practical testing of steam engines, important corrections are sometimes necessary, and it would be very desirable if a code bearing the authority of this Society could give a standard method of making these corrections. I have in mind a guarantee test of a 1,200 horse-power engine in which I was recently interested. The contract stated that the engine would be supplied with steam at 150 pounds gauge pressure and superheated 60 degrees at the throttle, and that the vacuum in the exhaust pipe would be 26 inches. On the test the steam was found to be superheated about 100 degrees, and the vacuum was 25½ inches. It would have saved an immense amount of discussion and annoyance if a code adopted by this Society had given a standard method of calculating the proper correction to be made for the difference between the actual superheat and vacuum from those required by the contract.

It is, of course, easier to criticise a report of this kind than it is to compile it, and I greatly appreciate the immense amount of work that has been required, on the part of the Committee, to bring the code to its present form. The criticisms which I have taken this opportunity to mention are, of course, merely the expression of a strong personal feeling in this matter, and as such it gives me great pleasure to submit them to the Society.

Mr. E. T. Sederholm.—The Committee is to be congratulated upon the thorough manner in which it has completed a very difficult and laborious task. There are, however, a few points to which I would like to call attention, in which it would have been well if the Committee had insisted more strongly upon accuracy as being the main thing to be desired, rather than conceding so much to convenience.

First of all, the Committee, while not advising, yet permits the use of water meters; yet we all know that even the best of them are notoriously inaccurate, and even the degree of inaccuracy is erratic. A little air in the water plays havoc with them, or a short stroke now and then is something which may go undetected during the calibration test. Furthermore, the valves *C*, *D*, and *F* in Fig. 1 are dangerous, for nothing is simpler than to shut valve *F* and open the other two, passing over an unlimited quantity of unmeasured water. Preferably, the connection between *C* and *D* should be broken entirely, or at least there should be no valve at *F*, but an open outlet.

The Committee leaves the door wide open for obtaining any results desired when it recommends that leakage of circulating water into the vacuum space of the surface condenser may be allowed for. Any leakage of any amount should simply invalidate the test, but it is altogether wrong, in my opinion, to allow the engineer in charge of a test to make these allowances after the loss has taken place. It is just such allowances which have made engineers hesitate in accepting many of the reported high results in tests of the past, and this Society ought not to countenance anything but that which has been *proven* correct. The same remarks apply, of course, to allowance for leakage from the air pump, unless such leakage is actually caught and measured.

The Committee suggests that where very large quantities of feed water have to be dealt with the orifice method may be adopted instead of that of weighing the water. In my opinion nothing but direct weighing or measuring in carefully calibrated tanks can be relied upon at all. What we want to obtain is incontrovertible facts, and the only difference between a small and a large plant is that for the latter everything has to be made on a larger scale, but the amounts involved are also larger, making it permissible. And certainly, the larger the plant, the more need is there for accuracy in the test, and not the reverse.

I quite fail to see why the Committee should establish what they term the "commercial ratio of expansion," when the Committee itself in the next paragraph admits that it is not the correct, the "ideal" ratio. Of what use is an incorrect ratio? And even the so-called ideal one recommended by the Committee is incorrect, for they assume that the final volume is equal to the piston displacement. It may be so in isolated cases, but more often it is not. The final volume depends to some degree upon the amount of steam which is retained in the cylinder at the point of compression. At first sight this may not appear to be the case, since the steam actually does expand so as to fill the whole low-pressure cylinder, including the clearance space. At the same time, the terminal pressure is in a large measure dependent upon the amount of steam retained at the end of compression, which steam at each stroke is added to that in the receiver, and then again

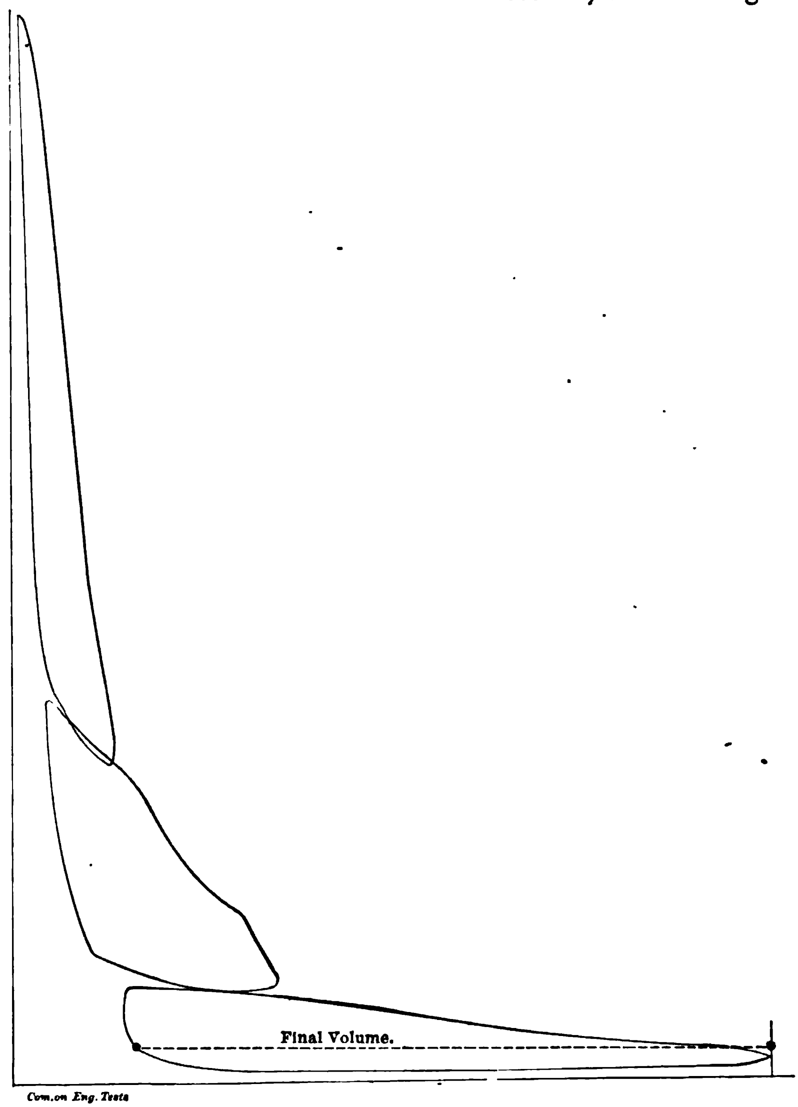


FIG. 144.—DIAGRAMS TAKEN DURING TRIALS OF STEAMSHIP "IONA" MADE BY A COMMITTEE OF THE INSTITUTE OF MECHANICAL ENGINEERS.

borrowed, so to say, by the cylinder for use during the expansion. The terminal pressure is therefore higher the more steam we confine in the clearance space, and the correct final volume is measured by a horizontal line on the diagram, drawn from the point of terminal pressure to the place where it intersects the cushion line.

The difference between the Committee's commercial ratio and this actual ratio is not by any means unimportant. I have in many instances compared the results of the two methods, and remember especially the case of the diagrams of the steamship "Iona's" engines, Fig. 144. The "commercial" ratio there is only 19.38, while the actual ratio is 30.3. The former would lead us to believe that great losses had taken place in the cylinders, quite unaccounted for, and we would wonder at the good economy shown in spite of such defects. The correct ratio shows us that these losses were only imaginary, and that in reality the actual diagrams very closely agree with what might be expected and with what can be predicted.

Prof. Gaetano Lanza.—I wish to make one comment. The Committee speaks of a radiation correction for a throttling calorimeter in Section xvi. of the report; whereas on page 198, Vol. xi. of the *Transactions*, it was shown by Professor Peabody that while the radiation correction would be considerable if an insufficient quantity of steam were run, it could be reduced to less than $\frac{1}{10}$ of 1 per cent. by simply running a sufficient quantity of steam through the calorimeter. In that paper there are some determinations of the amount of steam required for this purpose.

Prof. Sidney A. Reeve.—I will not take the time of the Society to attempt to express my appreciation of what the Committee has done. I will merely mention one point, and that is in the list of efficiencies. Professor Spangler has already expressed his sense of the limitation of attempting to express efficiency truly in terms of heat units. An engine operating under any given conditions has available a certain portion of the heat given to it for transformation into work. Of that heat available it transforms into work a certain portion. The skill with which the designer and constructor of the engine have fulfilled their mission is expressed entirely in this proportion. That ratio is to my mind the one figure which expresses most completely and perfectly the success and the value of the engine as a heat engine. To that ratio I ordinarily give the name "cylinder efficiency." I do not know of any authoritative name for it, but I make it the primary object of all engine testing to determine that figure. It is a figure which applies to any set of conditions, to any sort of engine, steam engine, gas engine, oil engine—any sort whatever—and for all of them it forms the only equitable basis for comparison of value. It entirely removes all difficulty in comparing different types of engines, because of different conditions of steam pressure or different ratios of expansion.

I think that this "cylinder efficiency" should be made the standard expression for the efficiency of an engine. For the purposes of the engineer the determination of that figure gives him all that he needs with the exception of knowing why the figure arises. To my mind the report would bring out more clearly the engineering side of the question, if that were made the standard efficiency, and afterward it were pointed out that the chief duty of the engineer is to so analyze the results as to see why the figure is as it is. For the commercial side of engine testing, the expression of efficiency in pounds of steam or pounds of coal is amply sufficient. For the engineer's purpose we want more scientific statements, and this cylinder efficiency, as I call it, is the only figure which gives scientific accuracy under all conditions.

Mr. W. H. Morse.—I should like to ask Professor Jacobus in closing the discussion to tell us whether the Committee have made any investigations as to the effect of steam at various temperatures on the accuracy of indicator springs, particularly in the more common types when the steam comes in direct contact with the spring. The whole engine trial depends upon the reliability of the indicator. If here we have an error of say 5 per cent., the accuracy of the trial is no better. This point is becoming more and more important in connection with gas engine trials and with superheated steam. I know that some elaborate investigations have recently been made under the auspices of one of the English societies on this point.

Mr. R. A. Smart.—In Section xx. (*d*) of the printed report, it is proposed to choose a theoretical point of cut-off, to be found at the intersection of the hyperbolic curve through the actual point of cut-off with a horizontal line through the highest point of the card, and call this assumed point the "commercial point of cut-off." It seems to me that if it is desirable to choose some point other than the actual point of cut-off for purposes of comparison, this should not be called the "commercial point of cut-off", but rather the "standard," or the "comparative" point of cut-off. Manufacturers of engines are frequently required to supply an engine which will cut-off at a given point. Such an engine will be set in the shop to give an *actual* cut-off of the specified amount. Now, when the purchaser indicates his engine and turns to the Committee for their designation of the point of cut-off, he will, if a layman, naturally conclude that what he wants is the "commercial point of cut-off," and will find that his engine is cutting off much longer than this. A change of terms, such as I have just indicated, would avoid the difficulty.

DISCUSSION ON THE FINAL FORM OF THE REPORT OF COMMITTEE ON STANDARDIZING ENGINE TESTS.*

Mr. Kent.—I am exceedingly gratified at this final revision of the steam engine Committee's report, especially because it has been very much changed since the last report of the Committee a year ago. I had occasion to make a test of a compound condensing engine recently where the guarantee provided that it should show a consumption of 13 pounds or less of steam per indicated horse-power per hour. As a matter of fact, it did show 12.8 pounds not including the steam used by the air and circulating pump, but about 14 pounds if this was included. The question then came up, had the engine filled its guarantee? The purchaser said the air and circulating pump should be included, while the engine seller said that they should not be included. The matter was referred to me, and I said that it was not, in the present stage of the case, an engineering question, and that as I did not propose to interpret the contract between the parties I would report the results both ways. The difference between the two results was less when the exhaust steam from the pumps was taken into the feed water heater. I wrote to Professor Jacobus about the matter, and asked him to consider it in his report, and I think the Committee has done so in a very satisfactory manner. Either method may be used, but it is a matter of the contract between the buyer and the seller as to which one should be used for the test. I have not had an opportunity to go carefully over the final revision of the report, but I am very much pleased with some of the changes, and I think we may congratulate ourselves on having such an excellent report.

I move that the report be received and printed, and the Committee discharged with the thanks of the Society.

* Presented at the New York meeting (December, 1902).

A Member.—I second that motion.

The Chairman.—Gentlemen, you have heard the motion. If it is your pleasure to receive the report and discharge the Committee with thanks you will signify it by saying aye—opposed, no.

Carried.

The Committee * desires to state in closing the discussion that they have carefully weighed the various criticisms and suggestions presented, and that the report as it now stands embodies their final conclusions. Some of the suggestions have been adopted, and the report changed from its earlier form. In regard to others, it should be said that they have either seemed to the Committee unwise, or, while the Committee recognized the force of the criticism, there appeared to be no satisfactory alternative. It may be seen by examining the discussions, which are here printed in full as orginally submitted, in what respects they have been either approved or disapproved.

---

* Closure by the Committee.

PAPERS

OF THE

SARATOGA MEETING

(XLVIIth)

OF THE

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

JUNE 23d TO 26th, 1903.

No. 975.

PROCEEDINGS

OF THE

SARATOGA MEETING

(XLVIIth)

OF THE

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

June 23d to 26th, 1903.

ALBERT L. ROHRER, *Chairman Local Committee.*
H. G. REIST, *Secretary of Local Committee.*
H. G. HAMMETT, *Treasurer of Local Committee.*

THE forty-seventh meeting of the American Society of Mechanical Engineers, was held in the city of Saratoga, N. Y., during the period June 23d–25th. The headquarters of the Society and the convention hall were in the United States Hotel.

The first session was called to order at 8.30, on the evening of Tuesday, June 23d, by President James M. Dodge, who introduced Mr. Albert L. Rohrer of Schenectady, Chairman of the Local Committee of members. In his welcome to the members, Mr. Rohrer called attention to the fact that the group of members contributing to the Saratoga Meeting included residents from Sandy Hill on the north, to Hudson on the south, and from Gloversville on the west to Pittsfield, Mass., on the east. He included in his welcome a greeting on behalf of the industrial corporations which were to be hosts of the Society during the stay of its members. The President of the Society responded to the welcome in fitting terms.

Professional papers were then taken up—the first by Mr. James M. B. Scheele describing the United States Army Gun Factory at Watervliet Arsenal, with respect to its working equipment, which the Society was to visit on Thursday. The following paper by Mr. R. P. Bolton, "Tests of an Hydraulic Elevator Plant," was discussed by Messrs. George Hill and John Balch Blood. Mr. Blood's paper on a "A Rational Train Resistance Formula" was discussed by Mr. H. W. Hibbard.

SECOND SESSION. WEDNESDAY, JUNE 24TH, 10 A.M.

The Secretary presented as the opening business of this session the report of the tellers appointed to count the ballots cast for members seeking election at this time. The report was as follows:

REPORT OF TELLERS OF ELECTION.

The undersigned were appointed a committee of the Council to act as tellers, under Article 11 of the Rules, to scrutinize and count the ballots cast for and against the candidates proposed for membership in their several grades in the American Society of Mechanical Engineers, and seeking election before the XLVIIth meeting, Saratoga, 1903.

They have met upon the designated day in the office of the Society and have proceeded to the discharge of their duty. They would certify, for formal insertion in the records of the Society, to the election of the following persons, whose names appear on the appended list, in their several grades.

There were 613 pink ballots cast of which 11 were thrown out because of informalities. The tellers have considered a ballot as informal which was not endorsed, or where the endorsement was made by facsimile or other stamp.

C. W. HUNT,
SAMUEL S. WEBBER, } *Tellers of Election.*
CHARLES H. CORBETT.

AS MEMBERS.

Atkins, Harold B.
Ayers, Hobart B.
Baehr, Wm. Alfred
Balkwill, Stephen, Jr.
Barton, Henry L.
Batchelder, Asa Fred
Becker, Wm. J.
Behn, Carl
Bishop, Chas. R.
Bliss, Collins P.
Bourne, Geo. Lewis
Breese, Chas. P.

Briggs, James Marvin
Budd, Edward G.
Burlingame, L. D.
Calder, John
Cameron, Barton H.
Clifford, Oliver C.
Cochrane, Robert B.
Cole, Dwight S.
Connell, John J.
Croxton, Herbert A.
Dally, John Horton
Doherty, Henry L.
Egan, Thomas P.
Ensign, Geo. A.
Fairburn, Wm. A.
Flint, Wm. P.
Gardner, G. Clinton, Jr.
Goodrich, Robt. R.
Gregory, Joseph N.
Harrison, Burt S.
Hart, Howard S.
Haskell, Broderick
Hassan, R. D.
Haughton, Frank A.
Jackson, John P.
Knight, Chas. F.
Lamy, Camille A.
Lane, Arthur M.
Lorsch, Edwin S.
McColl, J. R.
McGregor, Hugh R.
McMullin, Frank Van
McNaughton, James
Maddock, Geo. F.
Markham, Edw. R.
Martin, Simon
Mills, Edmund
Milson, Thos. H.
Mitchell, Guy E.
Morse, Wm. A.
Moss, Sanford A.
Muller, Paul
Murray, Geo. Robert
Newton, Lewis W.
Norton, Wendell P.
Oberauer, Ludwig
Park, Walter E.
Power, Pomeroy W.
Reid, Wm. L.
Sanderson, Edwin N.
Schulze-Pillot, Gehrard
Scott, Geo. W.
Spier, Chas. L.
Steen, Arthur B.
Stringham, Joseph S.
Sullivan, L. N.
Swenson, Bernard V.
Ten Broeck, Floyd G.
Thresher, Alfred A.
Troth, P. Howard
Upp, John W.
Wadsworth, Frank L. O.
Wells, Frank O.
West, Geo. W.
White, Arthur M.
Wiley, Edgar C.
Wraith, William

Promotion to Full Membership.

Allen, Charles M.
Allen, John R.
Barnay, John Martin
Burgan, A. L.
Carter, Henry W.
Cluett, Albert E.
Cooke, Harte
DePuy, Clarence E.
Eldred, Byron E.
Foster, Jed S.
Greene, Arthur M., Jr.
Gregory, Wm. B.
Kimber, Geo. Alfred
Lockwood, Edwin H.
Macpherson, J. D.
Meyer, Henry C., Jr.
Morse, Wm. H.
Ninde, Wm. E.
Patterson, Arthur W., Jr.
Redwood, I. I.
Sanderson, Edw. S.

As Associates.

Allen, Albert M.
Alvord, C. H.
Bary, Mark
Benton, Morris F.
Bower, J. G.
Chatain, Henri Geo.
Colburn, Geo. L.
Dalton, Hubert
Dinsmore, Samuel C.
Doughty, Geo. A.
Fergus, Wm. L.
Hartness, R. B.
Kinkead, James A.
Kuntz, Wellington W.
Larned, Stephen H.
Lucke, Chas. E.
Millspaugh, Wm. H.
Mundy, Wm. O.
Parker, Chas. H.
Pressinger, W. P.
Randolph, Clyde
Symington, E. H.
Watts, Geo. W.
Webster, Warren
Worcester, H. E.
Zohe, Ludwig A.

Promotion to Associate Membership.

Hunt, Wm. F.
Miner, Max H.
Moore, Stanley H.
Whitted, Thomas B.

As Junior Members.

Aldrich, J. Guy
Baker, Chas. H.
Bean, I. Mc C.
Bennett, T. Archibald
Brooks, R. Deane
Childs, H. P.
Cluett, Sanford L.
Cooke, Morris L.
Danforth, N. L.
Dauchy, Samuel Edwin
Dietz, Carl F.
Dixon, Chas. F.
Ducas, Charles
Estabrook, Mansfield
Fawcett, Wallace H.
Gagnier, Edward D.
Gifford, Albert James
Grover, Marcus A.
Halladay, Harry F.
Hanzlik, Henry
Hartwell, Hiram B.
Ilsley, John Parker, Jr.
Jackson, Arthur C.
Jones, Harold C.
Kapy, Artturi A.
Kennedy, Frank L.
McCoy, William
Macon, Wm. Watts
Marot, Edward H.
Merrill, Albert S.
Neave, Pierson M.
Nichols, John T.
Olmsted, Fay De V.
Payne, Nathan B.
Pennock, Geo. Alger
Ray, Fred
Richmond, Julian P. W.
Roberts, Edwin H.
Robertson, Chas. W.
Rumsey, Spencer S.
Sarengapani, T. S.
Schaefer, Edward F.
Schenck, Leon H.
Searing, Emery De F.
Seaver, Edward, Jr.
Shoudy, Wm. Allen
Stuntz, J. E.
Sweet, Franklin
Taft, Theo. H.
Thorpe, John C.
Tischner, Chas. F., Jr.
Toelle, Wm. Emil
Van Ness, Frank W.
Waters, Rossiter L.
White, Everett H.
Wilner, Elias R.
Wilson, Jacob D.
Wilson, Lester G.
Yarnall, D. Robert
Yaryan, Edward B.

The Secretary presented for record and publication in the volume of the *Transactions*, the circular which had been issued by the Council to advise the membership concerning the action which that body had taken pursuant to the announcement of the purpose of Mr. Andrew Carnegie to present a building for the uses of the profession of engineering, in which building this Society was to have an important share, both in the advantages and in the control. The circular had been sent by mail to every member, but it was thought desirable that the Society should take action in the general meeting upon the generous purpose of Mr. Carnegie and approve and confirm the action which the Council had already taken in advance of the general meeting. The circular of the Council forms an appendix to the Proceedings of this meeting. (No. 976, Appendix 1.)

Upon the announcement in this formal way of the action of Mr. Carnegie, Mr. Fred J. Miller offered the following set of resolutions:

The American Society of Mechanical Engineers assembled in general session at its 47th meeting in Saratoga, N. Y., has learned with the greatest interest of the proposed gift to the profession of engineering by Mr. Andrew Carnegie, member of the Society, of a million dollars for an engineering building.

The Society has also been informed of the action taken by its Council in reference to making this gift available and serviceable to the needs of this Society. Wherefore:

Be it *Resolved*, that this Society desires to place on record its appreciation of the purpose of Mr. Carnegie, in seeking to advance by this means the interests of the profession of engineering,

Resolved, That by embodying this purpose in the form of a great and noble building for the uses of those organizations whose aims are to foster the development of engineering, the donor has taken a step which will notably advance these interests:

Resolved, That the Society approves the prompt response of its Council to the opportunity offered to favor and further the interests of the Society which are involved in that progress of the profession which lies at the base of the Carnegie gift.

Resolved, That it be referred to the Council with power to transmit by cablegram and letter to Mr. Carnegie the action of the Society, and to carry out by further action, the details necessary to realize Mr. Carnegie's generous purpose.

On motion the Society expressed its sentiment upon the gift, and the resolutions accepting it, by a rising vote, which was unanimous. In seconding the resolutions, Mr. Henning spoke as follows:

Mr. Gus C. Henning.—In rising to second these resolutions I wish to compliment the mover of them on the lucidity, precision and appropriateness of the words which he has chosen to express our sentiments. I think the Society does itself great honor in taking this unanimous and wise action upon Mr. Carnegie's most generous gift. I think that it is understood that if the one million of dollars which has been mentioned does not meet the requirements of the building to be erected for the use of the associations, it is Mr. Carnegie's intention that sufficient funds should be provided to make the building adequate and satisfactory, so as to insure its completion and to meet the needs of the societies, not only for the present but for many years to come.

The Secretary presented a report on behalf of Mr. C. J. H. Woodbury, a delegate of the Society to represent it at a conference on Standard Electrical Rules, held in Boston in March, and which has incorporated in it an addition to the rules, dated June 1, 1903. The Society had been a participant in the original constitution of the body which formulated this national code, and had assigned its same representative to act for it in the 1903 conference as he had acted in the original conference in 1895. The report of this representative consisting of an addition to the National Standard Electrical Rules, is printed as an appendix to these minutes. (No. 977, Appendix 2.)

The next order of business was the presentation of the report of Messrs. H. C. Meyer, Jr., L. G. French and P. C. Idell, appointed as Tellers to count the returns on the letter ballot which had been issued by order of the Society to elicit the opinion of the members of the Society on certain questions brought out in connection with the discussion on the Metric System at the annual meeting. The form of the ballot was as follows:

OPINION ON THE METRIC SYSTEM AND H. R. BILL NO. 2054.

To the Special Tellers:

I desire to express my personal opinion on the questions which have been submitted to me concerning the advisability of the introduction of the Metric System and compulsory legislation on the same, by means of the cross in the square placed in the blank space upon the reverse of this sheet.

The cross is placed in the space opposite the vote which I desire to record. The absence of this cross indicates a negative vote on the question.

I wish to have it understood that this is a personal opinion and is not intended to form part of any official action of the American Society of Mechanical Engineers on this question.

Note—The ballot closes at 12 West 31st Street, New York, June 1st, 1903.

☐ In favor of the adoption of the Metric System of Weights and Measures as the only legal standard in the United States.

☐ Against adoption of the Metric System of Weights and Measures as the only legal standard in the United States.

☐ In favor of adoption of H. R. Bill No. 2054.

☐ Against adoption of H. R. Bill No. 2054.

☐ In favor of legislation which would promote adoption of the Metric System.

☐ Against legislation which would promote adoption of the Metric System.

☐ The substitution of the Metric for the English system would be detrimental to my business.

☐ The substitution of the Metric for the English system would not be detrimental to my business.

☐ The substitution of the Metric for the English system would be of advantage to my business.

It will be apparent that the form of the ballot was carefully worded so that it should appear an expression of opinion and not an official action or vote of the Society upon the questions asked. The Secretary explained that the circular and ballot had been sent to every member of the Society, members, associates and juniors, amounting to over 2,500. The number of replies in total of slips received was only 514, so that only about one-fifth or twenty per cent. of the membership had expressed an opinion on the question at all. It was further explained that the H. R. Bill, No. 2054, referred to in the slip which asked for opinion, was not the present form in which legislation was contemplated, but this ballot was an expression of opinion concerning a bill which was not under consideration at present, but which proposed to make the Metric System obligatory in the year 1902.

With these explanations the report of the Tellers was read as follows:

REPORT OF TELLERS UPON THE METRIC SYSTEM VOTE.

To the Council of the American Society of Mechanical Engineers:

Gentlemen:—The undersigned respectfully report that there were 514 ballots returned to the tellers by members of the Society. Of these five did not comply with the regulations and were not counted. The ballots were divided into nine headings, upon which expressions of opinion were asked. These headings and the number of votes cast for each, are as follows:

In favor of the adoption of the Metric System of Weights and Measures as the only legal standard in the United States	20 per cent.	103
Against adoption of the Metric System of Weights and Measures as the only legal standard in the United States....	80 per cent.	363
In favor of adoption of H. R. Bill No. 2054..............	20 per cent.	95
Against adoption of H. R. Bill No. 2054.................	80 per cent.	342
In favor of legislation which would promote adoption of the Metric System..................................	33 per cent.	153
Against legislation which would promote adoption of the Metric System..................................	66 per cent.	311
The substitution of the Metric for the English system would be detrimental to my business.......................	58 per cent.	243
The substitution of the Metric for the English system would not be detrimental to my business..................	42 per cent.	145
The substitution of the Metric for the English system would be of advantage to my business.....................		89

With the assistance of the office staff of the Secretary of the Society, the ballots were arranged in the classification shown on the attached sheet, to indicate the possible influence a member's occupation might have on his opinion in the matter. This classification is only approximately correct.

Very respectfully,

HENRY C. MEYER, JR.
LESTER G. FRENCH,
P. C. IDELL,
} *Tellers.*

	Foreign.	Draftsmen.	Railroad Men.	Teachers.	Mechanical and Consulting Engineers.	Juniors.	Business Men and Miscellaneous.
In favor of the adoption of the Metric System of Weights and Measures as the only legal standard in the United States....................	0	6	2	12	28	20	35
Against the adoption of the Metric System of Weights and Measures as the only legal standard in the United States.........................	3	9	14	27	86	50	174
In favor of adoption of H. R. Bill No. 2054.......................	0	5	0	15	25	20	30
Against adoption of H. R. Bill No. 2054	1	9	14	27	82	46	163
In favor of legislation which would promote adoption of the Metric System.	2	8	4	20	52	26	41
Against legislation which would promote adoption of the Metric System.	1	9	12	21	66	43	159
The substitution of the Metric for the English system would be detrimental to my business................	2	8	9	7	56	35	126
The substitution of the Metric for the English system would not be detrimental to my business.............	1	4	4	14	47	28	47
The substitution of the Metric for the English system would be of advantage to my business................	1	4	0	15	28	16	25

Some discussion ensued as to the advisability of making this report a matter of record, and certain members explained that they had refrained from voting by reason of the absence of experience with the Metric System sufficient to give them enough knowledge to form an opinion. It was the sense of the meeting that in view of the fact that this was a culmination of the discussions and action originating at the previous meeting, it would be impossible to escape the fact of the action whatever should be done with the record. A motion to keep the report off the records was finally withdrawn.

The next order of business was the report of the Society's Committee appointed at the Boston Meeting in June, 1902, to consider and report a Constitution, By-Laws and Rules for the Society, which should be a revision and amendment of those now in force. This Committee had been made to consist of Messrs. Charles Wallace Hunt, Jesse M. Smith, D. S. Jacobus, R. H. Soule, and George M. Basford. The report of the Committee had been sent by mail to all members, in April, with a request that they would send to the Committee any suggestions, amendments or improvements, in writing, that the Committee might consider these amendments in advance of the meeting and incorporate such as were desirable in a final report to be presented at this meeting. A revised draft or second edition of the Constitution, By-Laws and Rules had been prepared, incorporating many of these valuable suggestions, and was distributed at the meeting in the form in which it appears as an appendix to these minutes. (No. 978, Appendix 3.)

The text of the Committee's report was as follows:

REPORT OF THE COMMITTEE ON REVISION OF THE RULES AND METHODS.

The Committee on the Revision of Rules and Methods, in pursuance of instructions given them at the December meeting, beg leave to report that they have carefully reconsidered their work and have made such corrections as seemed advisable, and herewith present a draft of a Constitution, By-Laws and Rules, which they recommend for adoption by the Society by the procedure provided in the present rules requiring a letter ballot.

Immediately after the December meeting the Secretary sent a copy of the Constitution, By-Laws, and Rules presented to the meeting by the Committee, accompanied by a letter of the President, requesting members to send to the Committee such suggestions as they had to offer for the consideration of the Committee previous to its report at the Saratoga meeting.

Twenty-three written communications have been received in response to the President's letter inviting suggestions for the Committee to consider in advance of the meeting. There were ninety-five suggestions made, but as many of these were on the same subject the actual number for the Committee to consider was materially reduced. The importance of the suggestions varied from the omission of a comma to the insertion of new paragraphs. Every communication to the Committee was carefully reviewed, and each suggestion discussed, and such changes were made as seemed desirable, resulting in the draft now presented to you.

To illustrate the character of the changes that have been made other than punctuation marks and verbal corrections, consider Section C–2. Professor Kent pointed out that a change in the order of the clauses of this paragraph, placing "the maintenance of an Engineering Library" last, would be an improvement. This suggestion was adopted by the Committee.

Changes of a similar character have been made elsewhere, and the order of the sections has been changed in some cases to bring the sections treating of the same subject matter together, or in a more suitable place, for instance:—Sections R–9 and 10 were made R–14 and 15. B–40 was placed at the end of the By-Laws. The above class of changes did not affect the meaning or scope of the sections in any manner.

Another class of changes was made to correct obscure expressions, as in Sections C–9. Mr. Birkinbine suggested that the wording should be amended so that it could not be interpreted to mean that a teacher of engineering for five years or more can become a member, irrespective of his age. This was accomplished by dividing the paragraph into two sentences. The same changes were necessary in Sections C–10 and C–11.

A part of the paragraph C–21, relating to the present Junior Members has been taken from the Constitution and made R–17. This will permit this clause being dropped from the Rules by order of the Council as soon as it has served its purpose, without the formality of a vote by the membership at large, which would be necessary for a constitutional change.

A more important change was made in treating the subject of an independent Nominating Committee. It was clear that this provision should be a constitutional and not a by-law provision. C–48 and B–31 were adopted to accomplish the purpose. From this necessarily followed the change made in C–51, as the power of removing members of a committee by the Council should not apply to a Nominating Committee.

New sections have been inserted to cover some of the suggestions made to the Committee, such as—the status of guests of the members which had not heretofore been defined. Its necessity has developed since the Society has so largely increased in numbers. The Sections, B–24 and R–14 and 15 have been drafted to cover this case.

The laws of the State of New York, under which we are organized, empowers every member to vote by proxy at all meetings of the Society, and the provisions of the law have been incorporated in Section C–7, and the provision for carrying it into effect in B–41.

The Section C–59, relating to the method of amending the Constitution has had extended consideration by the Committee. The conclusion arrived at is that it is now the right of a member and a seconder to have a vote taken at any meeting of the Society. In all associations of this character it is the universal practice to have an amendment to the constitution presented to the membership for a vote whenever regularly presented by a member. The Committee did not deem it wise to abridge the right, but desired to hedge it round with such formalities as would make the mover take a sober second thought, both as to the subject matter and the form of the amendment.

The semi-annual meeting has been fixed as the time of offering an amendment in order that the principal discussion shall take place at the New York meeting, when the largest attendance may be expected.

The general procedure is that an amendment must be presented at a semi-annual meeting, and be open to discussion and to such amendment as the mover sees fit to accept. The amendment is then printed and mailed to the membership, and at the December meeting following, the subject is brought before the Society for discussion and amendments acceptable to the mover. A vote is then taken as to whether the amendment shall be submitted to the members for a letter ballot. If twenty members shall vote in favor of such submission, a letter ballot shall be taken in the manner prescribed in the By-Laws.

The important subject of protecting the Society from unsuitable candidates has been appreciated by the Committee, and the subject treated in the following manner. It is manifestly impossible for a member to personally know all the applicants for membership, and the Society cannot be adequately protected by a membership vote alone, no matter how fully the candidate's qualifications are presented to the voter.

A member receiving a list of candidates is entitled to know that each name has been carefully scrutinized as to the applicant's engineering qualifications, as well as his suitability for membership. To insure a careful consideration, the duties of the Membership Committee are specified in considerable detail in B-26. The sending out of the applicant's references and qualifications to the membership with a request for confidential communications, will develop unfavorable features if there are any, and the Committee will not pass the applicant's name forward to the Council if there is doubt of his engineering qualifications or his character. After an application has passed the scrutiny of the Membership Committee, the Council then passes upon it. It must receive their approval before it can go out to the members for a letter ballot.

Thus we have two bodies scrutinizing each application, a plan which it is thought will fully protect the Society and give an assurance to the voters that every precaution has been taken in each name presented to them for ballot. With this protection against unsuitable applicants, there is but little necessity for giving extended consideration to the number of adverse votes to defeat an election.

Paragraph C-16 has been drawn with an expectation that our Society will largely increase its membership in a few years. The number of adverse votes required to defeat an election in our present Rules is seven. This number was adopted when the Society was much smaller than at present. It is self-evident that as the membership increases this number should also be increased. The percentage scheme in the present draft will adjust the number automatically as the Society develops. If the proposed rule be applied to the Society at the time the present rule was adopted, the number of adverse votes to defeat an election would be practically the same as then specified.

As the Society increases in numbers, the burden upon the Secretary will increase, unless a material portion is assigned to the Standing Committees, as proposed in this Constitution.

There are six standing committees specified in C-45, each composed of five members. Especial care has been taken in Sections B-22 to 29, enumerating their duties, to call for frequent meetings, as well as to specify in considerable detail the duties they are to perform.

One of the first objects sought in the revision was to have each committee organized, so that only one member retires each year, thus enabling a committee to consider and adopt a policy and then to consistently carry it into execution.

This plan will bring into the active work of the Society thirty Members, Associates, and Juniors, in addition to the elective officers. This widening of the field of interested members seems a more desirable plan than to restrict the management, and the honors to the small number elected by ballot as would be the case if the Committees, or even the Chairmen, were to be selected from the Council. Usually the Council has only two or three members that can conveniently meet monthly for committee work, and to appoint those whose residence or business makes it inconvenient to attend meetings, is to invite imperfect or incomplete work.

The chairmanship of these committees will soon become posts of influence and high honor, and will attract men of ability, who will feel honored in giving the time necessary to carry on the committee work. Juniors cannot hold elective office under our Rules, but can become active and influential members of suitable standing committees.

Respectfully submitted,

C. W. Hunt.
Jesse M. Smith.
D. S. Jacobus.
R. H. Soule.
Geo. M. Basford.

At the close of the presentation of this report the Chairman presented the following resolutions:

Resolved, That the form of a Constitution, By-laws and Rules, presented by the Special Committee on Rules and Methods, be submitted to the membership for a letter ballot vote, as required in Article 45 of the present Rules.

Resolved, That the ballot shall close at eleven A.M. on the Wednesday following the first Tuesday in December next.

Resolved, That the Secretary shall verify the signature on the envelope inclosing each ballot cast.

Resolved, That the President shall appoint three tellers to canvass the vote and report the result thereof to the meeting.

These resolutions were duly seconded and the question was open for debate.

Mr. Gus C. Henning spoke in appreciation of the work of the Committee, and particularly of his pleasure in noting that the Committee had thought favorably of his suggestion concerning the creation of Sections of the Society. It was his opinion, however, that the importance of this idea was not sufficiently emphasized by making the organization of these sections a permissive matter in the discretion of the Council. He thought it should be obligatory upon the Council to proceed with the organization of the sections and recommended that the second article of the Constitution should be made to read as follows:

"C 2. The object of the Society is to promote the arts and sciences connected with engineering and mechanical construction. The principal means for this purpose shall be the creation of sections in such centres where a demand for them may arise; the holding of meetings of the Society and its sections, for the reading and discussion of professional papers, and for social intercourse; the publication and distribution of its papers for discussion, and the maintenance of an engineering library."

The Chairman of the Committee opposed the suggested change.

At the conclusion of the debate on this question the President put Mr. Henning's motion to amend; and it was lost.

Mr. Miller presented the following:

Mr. Fred J. Miller.—In regard to paragraph "C 12" it reads: "The rights and privileges of every member shall be personal to himself, and shall not be transferred or transmissible by his own acts or by the operation of law."

Now, it is explained by the Committee, in the first draft sent out, that this is a new article from a kindred society which emphasizes the fact that this is not a business Society, etc. I wish to ask if the Committee has assured itself that this does not really mean more than that? It says that no member by his own act may transfer any right which he possesses in the Society to any other member. That would apply to voting, and, if so, that is contrary to the law, because a member has a right to transfer his right to vote to any other member by giving him a proxy for that purpose. In after years, perhaps, after the events which have recently taken place in connection with this Society's affairs have passed out of men's minds, they may, in reading this over, conclude that they have no right to do things which as a matter of fact they have a right to do; they may not know that the law under which this Society is organized gives the right to every member of the Society to have his vote recorded on every question by means of a proxy, if he so desires.

Mr. Hunt.—That is covered in "C 7," which reads, "Honorary members, members and associates, are entitled to vote on all questions before any meeting of the Society, in person or by a proxy given to a voting member. A proxy shall not be valid for a greater time than six months." The other section mentioned is to prevent a claim on the assets of the Society either by the heirs of members, or by those who have been expelled from the Society. It has been found useful in another engineering society. The Committee inserted this section so as to have the members feel that it was a membership and not a business association.

The President then put the question on the adoption of Mr. Hunt's resolutions, which was carried.

Mr. Arthur M. Waitt moved that the Society tender a vote of thanks to the Committee for the very able work which they had done in connection with the matter referred to them.

The Secretary read the following letter from Mr. H. R. Towne, who had at one time been a member of the Committee and had taken part in some of its early work.

NEW YORK, *June* 17, 1903.

PROF. F. R. HUTTON,
Sec'y. A. S. M. E.,
12 West 31st St., N. Y.

Dear Sir:—At the proper time, during the discussion on the report of Mr. Hunt's committee on the revision of the Rules, I will thank you to introduce and place on record this brief expression of my opinion of the quality and value of the work of the committee.

Having long taken an interest in the subject, and having assisted the committee during the early stage of its work, I am in position to appreciate the vast amount of careful and intelligent study which the committee has devoted to its work, the outcome of which, when ratified by the membership, will give us a better Constitution and By-laws than those of any other Engineering Society of which I have knowledge.

I congratulate the committee on the completion of its labors, and the Society upon the improvement in the conduct of its affairs which will surely result under a plan of organization and of business which has been so carefully considered and so well devised.

Yours very truly,
HENRY R. TOWNE.

The President then called upon Prof. H. W. Spangler to present a report from the Committee which has been appointed to consider and report upon desirable specifications for boiler plate, steel forgings and steel castings. The report of this Committee and the debate on some of its recommendations appear as an appendix to these minutes. (No. 979, Appendix 4.) The Committee requested that it might have the benefit of any opinion upon its tentative report.

On motion of the Chairman the meeting approved the request that it should be sent to the members for discussion and comment, which was duly carried.

The President then read the following communication:

PHILADELPHIA, *June* 19, 1903.

TO THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS:

Gentlemen:—The Pennsylvania Railroad System has arranged with the Universal Exposition of 1904, at St. Louis, to install as a portion of its exhibit in the Department of Transportation, a Locomotive Laboratory, to be built upon the most approved designs, and to be operated during the seven months of the Exposition for testing locomotives.

The entire exhibit, including the locomotive laboratory, will be in charge of Mr. F. D. Casanave, Special Agent, who is authorized to act for the Pennsylvania Railroad System in all matters pertaining thereto.

It is the desire of the Pennsylvania Railroad System, as well as of the Exposition, that the series of tests to be conducted shall be upon the highest scientific basis, and the effort will be made to obtain results which will be of permanent value. The details of the plan have not yet been fully perfected, but it is expected that a large number of the most recent designs of American and European locomotives will be carefully and thoroughly tested.

In order that the best results possible may be attained, it has been decided to ask your honorable body, and the American Railway Master Mechanics' Association each to appoint an advisory committee of three members. The Pennsylvania Railroad System will provide all necessary apparatus and the force of engineers necessary to conduct the tests. It is desired that the advisory committee shall assist in laying out the programme of tests and in making the plans that are necessary to secure the most important and most reliable results. You are requested to appoint such a committee, and to select men who will be willing and able to give the necessary time and study to the subject. It is important that the plans should be effected at the earliest date possible in order to secure the hearty and full co-operation of the railroad companies and the locomotive builders, both in this country and in Europe.

It is our intention to ask the General Commissioners of the principal European countries to appoint, each, a mechanical engineer of high standing to represent those countries on the advisory committee.

Yours sincerely,

For the Pennsylvania Railroad System:

J. J. TURNER, *Third Vice-President.*

THEO. N. ELY, *Chief of Motive Power.*

For the Universal Exposition, 1904, St. Louis:

WILLARD H. SMITH, *Chief, Department of Transportation Exhibits.*

On motion the Society voted that such an "advisory committee" be appointed by the President in pursuance of the request in the communication. The President subsequently appointed Prof. W. F. M. Goss, J. E. Sague, and E. M. Herr such a committee.

The President then asked for any other general business, motions or resolutions, and none being presented the professional papers were taken up as follows: "Turbine Flow Recorder," by Charles M. Allen; "Some Data on Hoisting Hooks," by John L. Bacon; "Strains Produced by the Excessive Tightening of Nuts," by A. Bement; "An Indicating Anglemeter," by C. E. Sargent; "Recent Practice in Forcing, Shrinking, Driving and Running Fits and Limits for Limit Gauges," by Stanley

H. Moore. Messrs. F. A. Waldron, Gus. C. Henning, A. E. Johnson, Oberlin Smith, J. McGeorge, Fred J. Miller, Crane, N. Sanders, J. M. Sweeney, C. B. Calder participated in the discussion of these papers.

THIRD SESSION. WEDNESDAY, 2.30 P.M.

The papers for this session were as follows: "The Machine Shop Problem," by Charles Day; "Graphical Daily Balance in Manufacture," by H. L. Gantt; "Shop Management," by Fred W. Taylor; "The Steam Turbine from an Operating Standpoint," by F. A. Waldron. The discussion was participated in by Messrs. Taylor, Kent, Gantt, Calder, H. B. Ayers, Halsey, McGeorge, Mr. Peck (Schenectady), H. R. Towne, DuBrul, J. T. Hawkins, H. Emerson, Oberlin Smith, J. B. Blood, H. M. Lane, F. V. Henshaw, Gus. C. Henning, S. S. Webber, Pomeroy, A. M. Mattice, W. L. R. Emmett, C. V. Kerr.

On the evening of Wednesday a most entertaining programme had been arranged by the Local Committee for the pleasure of its guests. The "Jest and Song Club" of Schenectady, an organization made up principally from the young technical graduates bearing some relation to the works of the General Electric Company, had constituted itself a minstrel show with four end men at each end, with the historic bones and tambourines. The entertainment consisted of songs, choruses, a banjo solo, and a most enjoyable sleight-of-hand performance, interspersed with stories, which had nearly all of them an aspect of what are known as "grinds" upon members of the Society. It would be aside from the purpose of this formal record to repeat these, but they will not soon be forgotten by those who had the pleasure of listening to them. The entertainment will be one of the most pleasant memories which the visitors will take away from the Saratoga Meeting.

FOURTH SESSION. THURSDAY, JUNE 25TH, 9.30 A.M.

Professional papers were taken up as follows: "Experimental Boiler of Ohio State University," by E. A. Hitchcock; "Curves of Water Consumption for Various Horse-Powers of Several Engines," by D. S. Jacobus; "Drawing Office Equipment," by John McGeorge; "Bursting of Emery Wheels," by C. H.

Benjamin, and "Topical Discussion and Notes of Experience." Messrs. Allan Sterling, A. Bement, R. S. Hale, A. A. Cary, J. McGeorge, William Kent, G. I. Rockwood, C. V. Kerr, J. S. Coon, I. H. Reynolds, F. R. Low, J. H. Parker, J. Calder, F. W. Dean, E. H. Whitlock, F. A. Waldron, H. A. Richmond, Cole, E. H. Neff, L. P. Breckenridge, F. V. Henshaw participated in the discussion on these various subjects.

On the afternoon of Thursday the members were given opportunity to elect several alternative excursions. The larger numbers chose either the visit to Troy and Watervliet, or to the Spiers Falls plant of the Hudson River Power Company. The complete list of alternatives is as follows:

1. Mechanicville, Duncan Paper Mill and Hudson River Power Co. Station.
2. Watervliet Arsenal and Cluett, Peabody & Co. Factory at Troy.
3. Albany Filtration Plant.
4. Albany Capitol, City Hall and Park.

Leave by trolley for

5. Spiers Falls, New Power Plant of Hudson River Power Co.

Leave by D. & H. R. R. for

6. Sandy Hill to visit the new Sulphite Mill in the Union Bag & Paper Co's. Plant.

In the evening the Local Committee arranged for the reception to its visitors, in the ball-room of the United States Hotel. The Chairman of the Local Committee, and the President of the Society received the members as they entered the room, and the orchestra played for dancing after the collation.

Fifth Session. Friday, June 25th.

In the morning the members of the Society were made the guests of the American Locomotive Company, and were taken by special train to the yards of that company at Schenectady, where they were escorted through the plant under the guidance of the representatives of the company. Assembling at the charming grounds of the Mohawk Golf Club, just outside of the city limits, the members and their ladies were entertained at luncheon and the gentlemen adjourned to the session, which was held in the chapel of Union College. The members were welcomed by Prof. O. H. Landreth, member of the Society, in the absence of President A. V. V. Raymond, who specially invited the members to enjoy the stroll through the old college grounds if time permitted at the close of the session. The President of the Society in fitting words replied to the welcome, and called for the professional papers allotted to this meeting.

The paper by Mr. John Riddell, descriptive of the sixty-foot boring mill at the General Electric Company, was read by the Secretary, and the paper of Mr. Walter I. Slichter on "Alternating Current Motors for Variable Speeds" was read by the author. Mr. George W. Colles presented written discussion which was read by the Secretary, but the other participants in debate who had expressed their purpose to take part were not in the room. The final paper was by Mr. A. H. Eldredge on "Positive Governor Drives for Corliss Engines," which was discussed by Messrs. Cary and McGeorge.

The President took occasion at this session to announce under the provisions of Article 31 of the Rules, the constitution of the Nominating Committee, who should present nominations for officers of the Society, to be elected in advance of the annual meeting in December. He announced as the selected committee,

Messrs. JESSE M. SMITH, of New York,
F. W. TAYLOR, of Philadelphia,
ALEX. DOW, of Detroit,
WALTER MCFARLAND, of Pittsburg,
JAMES B. STANWOOD, of Cincinnati.

Before adjournment the Society expressed its thanks to Union College for the courtesy extended of the use of the chapel for this session.

The Secretary made brief reference to the heroic death of Mr. Edward Grafstrom, member of the Society, who had lost his life in the attempt to save the lives of others during the great Mississippi flood at Topeka, Kansas, in which city he was located as mechanical engineer of the Atchison, Topeka & Santa Fé Railroad. On motion of Mr. Henning, the Society directed that a suitable minute should be incorporated into the memorial notices of the year concerning the circumstances of Mr. Grafstrom's death.

The meeting then adjourned to be conveyed in trolley cars provided by the Local Committee, for a visit at the works of the General Electric Company in Schenectady, after which the train met the party in the yard, and conveyed it back to Saratoga.

CLOSING SESSION. FRIDAY, JUNE 26TH, 8.30 P.M.

The closing session of the convention was held in the evening on the return from the Schenectady excursion. Professional papers were as follows: "Tests of a 12-Horse-Power Gas Engine," by C. H. Robertson; "Performance of an Internal Combustion Engine Using Kerosene as Fuel," by H. F. Halladay and Mr. G. O. Hodge; "A Method of Testing Gas-Engines," by E. C. Oliver; "Hot Well as an Oil Extractor," by A. H. Eldredge; "Comparative Oil Tests," by W. F. Parish; "Tests of an Eight Foot Fan Blower," by E. S. Farwell. The only discussion was by F. R. Hutton and A. A. Cary.

At the close of the docket of papers, motions and resolutions were in order, and as a matter of form and compliance with the rules an opportunity was given at this point to discuss the proposed amendments as required in Article 45. No one availing himself of this opportunity, the Secretary presented the following resolutions on behalf of a committee appointed to draft them.

The American Society of Mechanical Engineers has been put under great obligation by the courtesies which it has enjoyed at the hands of its hosts during its Saratoga Convention.

The Society takes this way of expressing its thanks and recognition to these hosts for their generous intention, and for the successful carrying out of the entertainments during the stay of the visiting members.

1. *Resolved*, That the American Society of Mechanical Engineers extends to the American Locomotive Company, of Schenectady, its sincere thanks for the courtesy which has made the Society the guests of the Locomotive Company during the Schenectady trip on Friday. They would express their pleasure in the visit of inspection to the shops, and in the attention which surrounded the visitors during the entire day.

2. *Resolved*, That the Society extends its thanks to the General Electric Company for the invitation to visit its extensive works at Schenectady, and for the courtesies which were enjoyed during that visit. It would express its pleasure in the opportunity of seeing the scale on which modern electrical machinery is built to meet the industrial demands which the mechanical engineer has created, and its interest in seeing the special machinery which has been so developed to meet these new wants.

3. *Resolved*, That the thanks of the Society are due to the Duncan Paper Company of Mechanicville, for the invitation to include that establishment in the list of excursions planned for the afternoon of Thursday.

4. The Society would ask that Commandant Shaler, of the Watervliet Arsenal, would accept the sincere thanks of the Society for the courtesies enjoyed at his hand, and for the invitation which he secured from the General Ordnance Officer, that the Society should be the guests of the Arsenal, and of its Commandant on Thursday afternoon. It would express the pleasure of the visitors

that they should have had an opportunity to witness the operation of shrinking on a gun sleeve, and for the privilege of seeing the machinery and operations of the Arsenal so completely, and under such courteous guidance.

5. The Society would ask that Messrs. Cluett, Peabody & Company, of Troy, would accept the sincere thanks of those members who were privileged to visit their extensive plant and see the manifold operations which produce the results with which so many are familiar. It is true that fourteen thousand dozen does not express to most visitors an intelligible idea of numbers, and yet the magnitude of the establishment and the strenuous character of the processes which they inspected will not soon be forgotten.

6. *Resolved,* That the thanks of the Society are due and extended to the Union Bag & Paper Company, of Sandy Hill, for the invitation to include their works in the list of excursions enjoyed by the Society during the Saratoga Convention.

7. The American Society of Mechanical Engineers take pleasure in recognizing the courtesy which it has enjoyed from the faculty and trustees of the Union College in Schenectady, and of Dr. A. V. V. Raymond, President of the College, in the privilege of assembling for its Schenectady session in the Chapel of the Union College, and for other courtesies during its visit to that institution of learning.

The Mechanical Engineers are always prompt to recognize the close bond existing between its work and that of the educators, and to express the obligation which the practitioners of engineering owe to the earnestness and faithfulness of the teacher.

8. To Messrs. Baker & Shevlin, of Saratoga, the thanks of the Society are due for the courtesy of the invitation to visit their works and to study the interesting character of their shop equipment.

9. *Resolved,* That the American Society of Mechanical Engineers desires to record its special thanks and recognition to the Hudson River Power Company, and its capable and energetic President, Mr. E. A. Ashley, for the courtesies enjoyed at their hands on the occasion of the visit to the plant of that Company during the Saratoga convention.

The ladies in particular would ask that Mrs. Ashley would feel assured of the appreciation which they have felt for the interest which she took in their visit.

10. One of the pleasantest memories which the guests at Saratoga will carry away with them, and which will irradiate their glances as they look backward, will be that of the entertainment of the "Jest and Song Club," of Schenectady, on Wednesday evening. The temperance lecture embodied in the study of "A loss of head due to flow of liquids through an oral orifice; the memory of double barrelled politeness; of visits to Europe in the interest of the metric system; interwoven with most enjoyable music; and the achievement of the other artists will not soon be forgotten.

11. The ladies of the Society under its precedents do not have a voice in its public meetings and official acts. It must be left, therefore, for those who represent them, and who have been alleged in such formal acts as these to embrace the ladies to put on record on their behalf the thanks which should be transmitted to the ladies of the local committee of residents for their arrangements for the pleasure of the ladies upon the drives and excursions of the stay of the engineers in Saratoga. These drives and trips have been most thoroughly enjoyed in spite of the threatening and forbidding weather, and the Society asks that in this clumsy way it may try to voice the thanks of the visitors.

12. The American Society of Mechanical Engineers, in a long vista of successful meetings, is not likely soon to forget the delightful atmosphere which has pervaded the sessions of its XLVIIth meeting. It is to the local committee of resident members that the success of a meeting in its non-technical side must always be mainly due.

13. The Society asks that Mr. A. L. Rohrer, Mr. H. G. Reist, Secretary, and those who have acted as Chairmen of the Sub-Committees of their organizations, will accept the sincere thanks of the visitors for the admirable programme prepared with so much care in advance of the meeting, and for the effective and energetic measures taken to carry out the provisions and arrangements of the meeting.

The Society would ask that through the Committee they may be able to reach all those individuals, firms and organizations which have placed the Society in its debt, and would ask that the local committee will carry in their memories this expression of heartfelt recognition for one of the most enjoyable meetings in the history of the Society.

14. *Resolved,* That a copy of these resolutions be furnished to the *Daily Saratogian.*

At the close of the reading of these resolutions, which were unanimously adopted, the President asked for any further business, and none being presented he asked the Society to accept his sincere thanks for the kindly way in which it had treated him during the sessions, and announced the meeting adjourned.

The register showed that during the four days of the meeting there were 315 members in attendance.

No. 976.*

THE CARNEGIE GIFT TO ENGINEERING.

The Council takes great pleasure in announcing officially to the members of The American Society of Mechanical Engineers, that Mr. Andrew Carnegie, a member of the Society, has presented to the profession of Engineering a notable gift. His letter of presentation is as follows:

"2 East 91st Street,
"New York, *February* 14th, 1903.

"Gentlemen of the American Society of Civil Engineers,
American Society of Mechanical Engineers,
American Institute of Mining Engineers,
American Institute of Electrical Engineers,
and The Engineers' Club.

It will give me great pleasure to give, say, one million dollars to erect a suitable Union Building for you all, as the same may be needed.

"With best wishes,
"Truly yours,
"(Signed) Andrew Carnegie."

It is the purpose of this munificent donation to bring the libraries, assembly halls, offices and meeting rooms of the various organizations which shall enter into this enterprise into one great building, specifically devoted to engineering, ample in size for individual privacy and at the same time arranged definitely for their convenient business and professional uses. The building will, in addition, provide a meeting place, both suitable and adequate, for such technical, scientific, and engineering bodies as may desire the use of a properly equipped auditorium, together with accommodations for their offices, if such shall be

* Appendix No. 1 to the Proceedings.

needed. It has been particularly the wish of Mr. Carnegie, as with many others interested in engineering, that the profession should be brought nearer together, both as professional men and as individuals, and on the social as well as on the technical or scientific side. The social function of the Engineers' Club seemed a happily chosen agency for this end, and it has been utilized by including this body in the benefits planned by Mr. Carnegie. The form of the provisions for organization and control, which have been embodied in the resolutions which have been acted on by the Council, make this conception still more evident.

The societies named in the letter of Mr. Carnegie will be the property-holding body, but of course this is with full intention that by lease or other arrangement the building shall provide the necessary accommodation for other organizations of kindred aim, which may properly attach themselves to such an engineering center. A building of a frontage of 125 feet and with a height of ten stories, devoted to the advancement of engineering, will be in itself a monument to engineering, in which the profession may well feel a pride.

It should be carefully observed that each society is to preserve its own control of its own affairs just as much as if each body was in an isolated building. The management of the Engineers' Club is entirely separate from that of the engineering societies, so that the latter are entirely free from any responsibility financial or otherwise which may arise in the management of the club. There is no purpose at present to interchange membership privileges. The financial interest which each society will assume in the undertaking, will be represented either in the form of bonds bearing interest, which will be issued by a real estate-holding corporation, or in some other form which shall be satisfactory to the joint committee representing the societies.

As the officers of the societies named in the gift could not act until duly authorized by their respective governing bodies, Mr. Carnegie authorized his representative, Mr. R. A. Franks, in the following letter, to advance at once the sum necessary to purchase options upon desirable property, abutting on the lots on 40th Street, which were already owned by the Engineers' Club. This abutting property was found on the north side of 39th Street, Nos. 23, 25, 27, 29, 31 West 39th Street. Mr.

Franks' letter was to the chairman of a sub-committee appointed informally by representatives of the various societies, and is as follows:

"HOBOKEN, N. J., *May* 13, 1903.

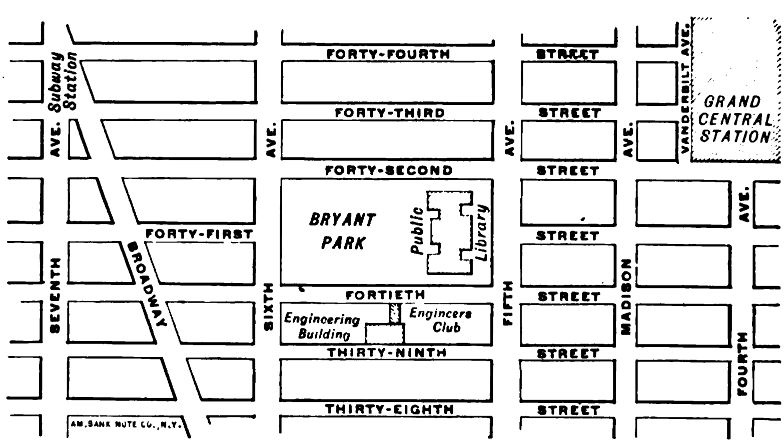
"DEAR MR. KAFER: I have yours of the 11th instant, and in reply would say that Mr. Carnegie has authorized me to pay for options on property for new Engineering Building, also to furnish the funds for the purchase of property to be used for site for the building. I am therefore in position to pay the amount required to hold the property referred to in your letter, and to pay for the lots if they be secured.

"Yours very truly,

"(Signed) R. A. FRANKS."

It was apparent that this matter had to be consummated before the proposition became a matter of public information. The sub-committee took up the matter at once, and the options were secured in a few days at satisfactory prices, Mr. Franks advancing for this purpose fifty thousand dollars.

The accompanying sketch map shows the general scheme of the enterprise. The plot on 40th Street owned by the Engineers' Club has a frontage of 50 feet and a depth of 100. The plot on 39th Street has a frontage of 125 feet with a depth of 100 feet. The combined area of the two holdings is 17,500 square feet.



It will be apparent on inspection that this location is one of the most eligible ones in the City of New York. The New York Public Library building occupies the entire eastern frontage of the block between 40th and 42d Street on Fifth Avenue, while to the westward of it is the open square known as Bryant Park. It will be conveniently accessible from the terminals of the New York, New Haven and Hartford Railroad, and the New York Central and Hudson River Railroad at 42d Street, at Park and Madison Avenues, and from the Pennsylvania terminal coming in from the west, at 33d Street and Seventh Avenue. The elevated railway, on Sixth Avenue has a station at 42d Street and the Third Avenue elevated at 42d Street and Park Avenue. The junction of the Rapid Transit underground lines at 43d Street and Broadway makes this an important express station both from down town and from the north. Convenient surface lines both up and down town and cross town intersect at 42d Street. The hotel district of the city is centering around this particular region.

After the options on the land have been secured by its subcommittee, the presidents of the societies named in the letter of gift met on April 30th for conference, and issued to the governing bodies of the participant societies an official communication in pamphlet form containing Mr. Carnegie's letter and a proposed draft of resolutions whereby the acceptance of the gift might be realized. Pursuant to this call the Council of the American Society of Mechanical Engineers met on Thursday, May 7, 1903, with an unusually large attendance of seventeen members, and by unanimous vote the resolutions were passed, and were again confirmed and elaborated by resolutions passed at a second meeting of the Council held on May 27, 1903. The resolution of the Council under which the Society accepts the gift of Mr. Carnegie and assumes its share in the management of the great trust which he has created for the advancement of the profession of engineering, and to secure the recognition both in the community and in the world at large which should attach to engineering in its broad acceptation, took the following form:

Resolved, That the American Society of Mechanical Engineers shall unite with The American Society of Civil Engineers, the American Institute of Electrical Engineers, The American Institute of Mining Engineers, and The Engineers' Club, or any of them, for the purpose of accepting the sum of one million dollars as a gift from Mr. Andrew Carnegie, for the purpose of erecting suitable buildings for occupancy by various societies of engineers, and the Engineers' Club, on the sites located for that purpose on the north side of 39th Street and south side of 40th

Street west of Fifth Avenue, in the City of New York, in the State of New York.

2. *And resolved further*, That the American Society of Mechanical Engineers has a very high appreciation of this very generous gift of Mr. Andrew Carnegie, and this additional evidence of his recognition of the engineering profession and his deep interest in the welfare of the national societies of engineers and the Engineers' Club.

3. *And resolved further*, That a site on the north side of 39th Street shall be purchased and held by trustees or otherwise as shall be determined by the Joint Committee hereinafter mentioned, for The American Society of Mechanical Engineers, The American Society of Civil Engineers, The American Institute of Electrical Engineers, and The American Institute of Mining Engineers, or by such of them as shall vote in favor of coming into this enterprise.

4. *And resolved further*, That a Joint Committee shall be created to be composed of three members of each organization that shall unite in accepting said gift of one million dollars from Mr. Andrew Carnegie; and that the governing body of The American Society of Mechanical Engineers shall elect three members of this Society to represent it on and be members of such Joint Committee; and that the governing body of The American Society of Mechanical Engineers shall have the right and power to remove any member of such Joint Committee who shall be elected by it and to elect any member of this Society to fill any vacancy that shall occur in such Joint Committee by reason of the death, resignation, or refusal to act or by the removal of any member who shall have been elected by the Council of this Society as a member of such Joint Committee.

5. *And resolved further*, That the character and internal arrangement of the building to be erected on site on 39th Street, shall be determined upon by the affirmative vote of at least two-thirds of all of such of the members of said Joint Committee as shall represent all of the organizations other than the Engineers' Club on such Joint Committee; and that the character and internal arrangement of the club building to be erected on the site on 40th Street shall be determined upon by the affirmative vote of all of the three members of such Joint Committee who shall represent the Engineers' Club on such Joint Committee; and that the apportionment of funds between the two buildings shall be determined by an affirmative vote of two-thirds of the entire Joint Committee.

6. *And resolved further*, That said Joint Committee shall by the affirmative vote of at least two-thirds of all the members thereof, select and employ an architect and such consulting engineers as may be necessary, to prepare the plans and specifications for the building to be erected on the site on 39th Street and for the club building to be erected on the site on 40th

Street; and shall also obtain proposals for the erection of both of such buildings; and shall have power to make and enter into such contract or contracts as shall be approved and authorized by the affirmative vote of at least two-thirds of all of the members of said Joint Committee for the erection of both of such buildings; and shall have charge of the erection of both of such buildings.

7. *And resolved further*, That said Joint Committee shall continue in existence until all of the purposes set forth in these resolutions shall have been fully accomplished.

It will be recalled by the older members of the Society, that within the first ten years of its history a movement was started in which members of the Society were participant to secure a joint building to be erected as an investment, and which should give accommodation to the libraries and executive offices of this and the other engineering societies, and to secure the advantages of a common assembly hall. To be of any significance in accommodating its annual meetings, with the Society of its present size, the auditorium should be able to seat over 600 persons.

In 1890, when the Society secured its present house at No. 12 West 31st Street, a move in this same direction was made again, with a view to bringing the Institute of Mining Engineers and the Institute of Electrical Engineers into joint occupancy and common use of library and assembly hall. The Institute of Electrical Engineers joined in the undertaking at that time, and is still holding its meetings in the auditorium of the Society House.

With the increasing growth of the Society, and the unusual attendance at its annual meetings, the auditorium has already proved inadequate, and the growing library has been for some time crowding the space available in the present building. This Society has therefore felt a lively interest in bringing about some result which should secure adequate accommodations for its library and for its large meetings. There seemed reasons of weight why it was neither judicious nor desirable for this Society to undertake the erection of a house for its exclusive occupancy on a scale which should furnish the floor space for an adequate auditorium in addition to its library and offices.

Upon the carrying out of the proposed plan the present Society house at No. 12 West 31st Street can either be retained and rented to a suitable tenant, or it can be sold on advantageous terms, which will nearly pay the share of the Society in the real estate holding of the Society in the 39th Street site. Rentals from kindred societies for the use of offices and meeting places in the new building, not needed by the owning societies, will reduce interest charges on the land.

It is the desire of the Council, pursuant to the foregoing announcement and report, that at the approaching meeting of the Society in general session the members should take appropriate action outlining the position which they deem desirable that the Society and the Council shall assume, in the disposition of its real estate and in administering the great trust and responsibility which Mr. Carnegie's gift has imposed. It may be added that the Institute of Electrical Engineers and the Engineers' Club have already taken action by adopting the same resolutions as those adopted by the Council of this Society, and have appointed their members of the Joint Committee so that the acceptance of Mr. Carnegie's gift is already assured. The Council of this Society has appointed as members of the Joint Committee provided for in the resolutions, the following representatives:

Mr. James M. Dodge, President,
Mr. Frederick R. Hutton, Secretary,
Mr. Charles Wallace Hunt, Past-President.

The American Institute of Electrical Engineers has appointed

Mr. Charles F. Scott, President,
Mr. B. J. Arnold,
Mr. S. S. Wheeler.

The Engineers' Club has appointed

Mr. John Kafer, President,
Mr. W. A. Redding, Chairman House Committee,
Mr. W. H. Fletcher.

The American Institute of Mining Engineers and the American Society of Civil Engineers are expected to take favorable action in due time.

APPENDIX.

The Council has thought that it would be of interest to the members to add in an appendix the opinions of representative writers and leaders of thought. The opinion held by Mr. John Fritz, Past-President and Honorary Member of this Society, has been eloquently set forth in the following letter prepared at the request of the representative committee of the societies. It adds interest to this letter and its opinion to remind engineers that Mr. Fritz has been recently honored by joint action of the four engineering societies, by the founding of a medal which is to bear his name, and which is to signalize achievement in one of the branches of engineering or science.

Mr. Fritz's letter is as follows:

"BETHLEHEM, PA., *April* 29, 1903.

"MY DEAR MR. SCOTT: Yours of the 25th asking for a statement, on general lines, expressing my views regarding the proposed project of housing the Civil, Mining, Mechanical and Electrical Engineers, all in one building, is at hand. This, for me, is a somewhat difficult task, as I am unaccustomed to either speaking or writing, but I will do the best I can in my own way, recognizing that a defective statement is much less humiliating and less expensive than bad engineering.

"The object of our meeting to-night is not new to me, but it is most interesting; for some years before the death of our lamented Holley, he and I had many talks on the subject that has called us together.

"At that time, the most we hoped to accomplish was to devise some means that would bring the engineering societies in closer touch with each other. We had a scheme which we thought was practicable, and would at least in a measure accomplish the purpose; but there were difficulties in the way and the project was quietly laid aside.

"About that time, too, Mr. Andrew Carnegie was laying the foundation for his stupendous fortune, and now in his great generosity, and in recognition of the merit of the engineer, and mindful of the assistance he received from them during his most remarkably successful career, he has so nobly offered to give the money to purchase the lot and erect a building that will accommodate the four great engineering societies, and the Engineers' Club, separately; which will be a monument to the engineering profession and will let the world know that there is one man who knows and acknowledges their work and worth.

"When Mr. Holley and I talked over some plans to bring the engineers closer together, the wildest flight of our imagination could not have conceived the idea of such a magnificent gift as is now presented to us, for the fulfillment of the object that was then so near our hearts.

"There is something so beautiful and encouraging to the young men to know that the donor was at that time *one of us*, the same as the young men of to-day, who was struggling for recognition amongst the business men of the country, the same as you are for place in the line of your profession. And I beg to say that, in my humble opinion, the occupation of the engineer is one of the grandest, most useful and far reaching that falls to the lot of man to pursue; and I know of no calling that requires more thoughtful and careful study than that which inspires and pervades the profession; nor is there any society or class of people that the world is so much indebted to as the engineer.

"I shall now treat them as *one family* and recognize the beneficence of their united efforts. The value of their genius and influence and what they have accomplished cannot be estimated or restricted to any one country. They are only bound by the law of progress; which means that each triumph of their genius inspires them to higher and grander accomplishments. There seems to be no finality to their progress, unless the nations of the earth lapse into barbarity. Look at the vast system of railroads that space the continent, that has reduced the time of traveling from ocean to ocean to nearly the same number of days as formerly required months. They have carried civilization and commerce throughout the great wild west, converting it into farms now occupied by an industrious, intelligent and happy people. Then, again, think of the navy we have built and are building; also think of the most remarkable performance of the battleship "Oregon," sailing from Puget Sound, on the North Pacific coast, around Cape Horn to Santiago, and then forthwith going into action without any repairs of any kind: a feat unparalleled in the history of battleships. It was the navy of *our* construction, which we are all so proud of, and justly so, that made it possible for us to achieve the victory over the Spaniards in Cuba; which placed our country in the front rank of the great nations of the world. I now ask who built our great system of railroads, who designed and built the ships of our honored navy, and thousands of other works of merit that could be mentioned? The answer is *the engineer*. But no one Society of Engineers can claim that its members did it all; *for it has all been accomplished by their united efforts*. I most ardently hope they may still become more closely associated, both on social and on engineering lines.

"The societies are so interdependent, and overlap each other to such an extent, that to me it is most surprisingly strange that the efforts which have been made before this time to bring them in closer contact with each other, has not been successful.

"It has been my fortune to have good friends in the various societies; and we were, at all times, ready and willing and happy to exchange ideas with each other; and I am absolutely certain that we all profited by it, and the country at large received the benefit.

"When I first went to work in the rolling mill and would go near the roll turner, he would take up his templates and put them in his pocket. I am happy to say that the people are becoming more tolerant; that the conditions of the country have greatly changed and we must be prepared to meet them. What is now wanted is well-informed, liberal, broad-minded and many-sided men; and I am a firm believer, all other things being equal, that every man should know something of everything and everything of something.

"I could give you instance after instance from my own experience, which would prove the correctness of the foregoing views.

"Now, the only way that I can see to obtain this knowledge is to get close together. By pursuing this method, all parties will be benefited and they will obtain certain practical knowledge and advantages that cannot be otherwise obtained. And I know of no plan by which this can be so well accomplished as that proposed, where all the specialists can conveniently meet each other and at the same time have access, under proper rules, to the various libraries. This would be the college of colleges.

"The Electrical Institute, though the youngest, has great possibilities before it, and may be the means through which the older societies can be brought together. The members of this society are young and pliable; who are dealing with an element that requires them to be ever on the alert, and who well know the value of cumulative knowledge.

"As there has been nothing said regarding the Marine and Naval engineers, I have made no specific allusion to them; but I would like to see them all included, and also both the physical and analytical chemists.

"Finally, it is the young men who will derive the greatest advantage by the adoption of the proposed plan. Should this plan fail, and were I a young man, knowing what I now do on the subject, it would be one of the objects of my life to devise some means by which the younger members of our profession could be brought into closer unity.

"Sincerely hoping for complete success, I am,

"Yours most truly,

"(Signed) John Fritz."

Mr. Charles F. Scott, President of the American Institute of Electrical Engineers, has contributed the following:

"The four general engineering societies named by Mr. Carnegie are but a part of the engineering societies which are to be benefited by a Union Engineering Building. There are numerous societies—many of them strong and vigorous—whose membership contained many of the members of the general societies but whose fields of activity are specialized in their scope. The work of these societies is of a high order, and taken in the aggregate it is a most important part of American engineering. Definite permanent headquarters and accommodations in the same building with those of other societies will be advantageous to the societies themselves, and will be of great convenience to their members.

"Some of the uses and advantages of a Union Engineering Building may be indicated in a general way without entering upon details.

"A large assembly hall will be available for lectures and for the holding of general conventions of engineering societies.

"A number of smaller halls will accommodate smaller audiences and will be suitable for monthly meetings of societies and for sectional or supplemental meetings at the time of conventions.

"The libraries of the several engineering societies placed in adjacent alcoves or rooms will constitute a magnificent engineering library. Economies will be effected as many books need not be duplicated which would be necessary if the libraries were separate, and there may be reduced cost for administration. The several libraries may have a common index. Moreover, the Union Engineering Library will be adjacent to the new building of the New York Public Library, 40th and 42d Streets.

"Rooms may be available for reading and writing. The building itself may become a gallery of portraits of eminent engineers and illustrations of engineering works.

"Accommodations for the administrative offices of the several engineering societies may be arranged to suit their various needs. Facilities for the officers, boards of direction, committees, as well as for the mailing, and possibly the printing, of transactions may be afforded.

"Facilities may be arranged for the serving of luncheons or dinners at the time of conventions or meetings and for the holding of formal dinners and banquets. A common cuisine may serve the Engineers' Club and the engineering societies.

"The idea of Mr. Carnegie is significant in its very breadth. He has not imposed restrictions nor introduced details. In a single sentence he has presented a great opportunity, and places confidence in engineers that they will adequately meet it. The present is the time to expand; to construct a magnificent ideal; to picture what should be done, and to devise how it may be accomplished. Let us first develop our grand ideal. There are plans to be arranged and details, perhaps perplexing, are to be worked out. Engineers are now called to work out for themselves a problem similar to those which they are continually solving for others.

"To us is committed a great trust on behalf of American Engineering. The real question to be decided is not whether we will accept it, but it is whether we can take the responsibility of refusing to administer it."

At the annual dinner of the Institute of Electrical Engineers on February 9, 1903, Mr. Carnegie in the course of an address revealed his mind on this general question in the following quotation:

"I have often taken occasion to say—and I have known both lands well—that the American engineers are the most co-operative men, I believe, that exist to-day. I think there is harmonizing feature about them which counts for everything in the progress of any great movement, political, social or scientific. It is institutions like this of engineers which do so much: you cannot overestimate the influence which such organizations exert."

At a meeting of The Municipal Engineers of the City of New York, held in the rooms of The American Society of Mechanical Engineers on May 27, 1903, the following preamble and resolutions, presented by a committee consisting of Messrs. O. F. Nichols, Chairman, Henry R. Asserson and Samuel C. Thompson, were enthusiastically adopted:

Whereas, Mr. Andrew Carnegie has, in a letter addressed to the four national engineering societies and The Engineers' Club, generously offered to give the sum of about one million dollars ($1,000,000) for the construction of a building to be devoted to the general interests of American engineering; and,

Whereas, The spirit and dimensions of the gift indicate the intention of the liberal donor that the building should be used in the broadest and fullest extent by American engineers; therefore,

Resolved, That the Society desires to express its profound appreciation of the broad interest taken by Mr. Carnegie in American engineering and the generous gift by which he has characterized this interest, and

Resolved, That this Society of Municipal Engineers of the City of New York hereby expresses its earnest hope that the five organizations to which Mr. Carnegie addressed his offer will unanimously accept the magnificent gift, and work in the fullest harmony to carry out the trusts imposed upon them by the donor for the advancement of American engineering.

I am instructed to send a copy of these resolutions to you, with the request that you present them to the committee of your Society which is acting in the matter of the proposed union engineering building.

Yours very truly,
WINNER MARTIN,
Secretary.

From various technical journals the following editorial comments have been culled:

"AMERICAN MACHINIST."

Upon the whole the engineers have a great task upon their hands, and it should be as successful as American engineering work already is in its other fields of occupation. In this day of successful combinations it will be a disgrace to American engineers if they for any reason fail to put this project through.

No small ideas should have any chance.

"ENGINEERING NEWS."

We think it is worth large emphasis that this great gift from Mr. Carnegie comes unsolicited. The engineering societies of America are great educational institutions for the advancement and upbuilding of the profession; but they are not organizations in need of charity. It is because Mr. Carnegie saw and appreciated the great advantage to the engineering profession of the union and co-operation that might be brought about, that he decided to make this great benefaction.

The influence and value of such an engineering center to the entire profession is too obvious to call for comment.

"RAILROAD GAZETTE."

The gift is a fitting recognition of the work and importance of the engineer, and is made doubly significant by the character of the giver; one whose life and fortunes have been so closely allied to the engineering profession.

In any event, the erection of a union building, and the added availability of their several libraries, will do much to unify the kindred interests of engineers, and it will be a concrete reminder of the potent influences which are being and have been exerted in the affairs of mankind by that noblest and most dignified profession.

"ELECTRICAL REVIEW."

It would seem that the joint ownership of an Engineering Building, in which individual engineers should meet members of other engineering professions, would give each a broader view of the aims of his brother engineers than could be gained in any other way.

We believe that there are few ways in which Mr. Carnegie could have done more for the general welfare.

"The Engineering and Mining Journal."

The best feature of such a central building lies in the fact that it will afford a convenient rendezvous for all engineers in good standing and those birds of passage, more particularly the Mining Engineers, will have a place to set their feet. If the idea is carried out to its complete fulfillment, it means that the band of men "who give expression to that combination of contemporary science, art, knowledge and practice which we recognize as modern engineering," will be enabled to meet amid a favorable environment and consummate the purpose of all such gatherings, namely, to discover one another, to give the right hand of fellowship, to make common cause against the Fool.

"Electrical World and Engineer."

This gift of Mr. Carnegie to the societies of which he is a member and representing the professions to which he is glad to acknowledge his indebtedness, comes "without strings," but it has, nevertheless, serious obligations. The Engineers' Club has already provided itself with land, but the four engineering bodies named specifically have to do with a real estate transaction of between five and six hundred thousand dollars. In fact, the necessary steps have already been taken to secure the land, and at this moment the Union Engineering Building is to be regarded as a tangible actuality. When we remember that the societies in question have at least ten thousand members in good standing, the financial responsibility upon them dwindles into insignificance. Even if one or other of them should not feel able or willing to come in, there is all the more left for those which do respond to this clarion call to co-operation.

In no particular will any society be urged to surrender its autonomy or self-respect. But it is always easier to find reasons for grimly standing apart, than to hit upon methods of harmonious union; and just now the men in each body who believe that civilization itself is based on "getting together" for the common good, have their opportunity to benefit the profession to which they belong, by making the most of the situation.

"The New York Times."

No branch of engineering can stand alone. Results of value are obtained by co-operation and co-ordination.

To the members of several technical societies the relatively wide separation of their respective headquarters has long been an inconvenience, and the fact that there has been no common meeting ground for engineers resident in or visiting New York has been a distinct deprivation.

The location agreed upon is probably the best which could be found on the American continent. For the next quarter of a century at least it will be close to the business center of New York. It is also the center of the hotel district and of everything pertaining to the characteristic life of the metropolis. It is doubtful if any library foundation with which Mr. Carnegie's name is identified will ever accomplish as much benefit in promoting the progress of the arts and sciences as will result from his unconditional and unrestricted offer of a home for engineers. As Mr. John Fritz feelingly and forcibly says: "There is something beautiful and encouraging to the young men to know that the donor was one of us, the same as the young men of to-day, struggling for recognition among the business men of the country, and, as you are, for place in the line of your profession." Mr. Carnegie could not have selected a more intelligently appreciative body of men to co-operate with, and those who heard his speech at the recent annual dinner of the American Institute of Electrical Engineers when he told how he worked his way up from a job in the cellar tending a small motor to a place at the key as a telegraph operator, will perhaps not find it difficult to understand why he experiences pleasure in thus prominently identifying himself with the profession which has contributed so largely to his success.

No. 977.*

REPORT ON MEETING OF NATIONAL CONFERENCE ON STANDARD ELECTRIC LIGHTING RULES.

TO THE COUNCIL OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS:

Gentlemen: The undersigned as a delegate of the American Society of Mechanical Engineers to the National Conference on Standard Electrical Rules, which was held at New York, March 18–19, 1895, and which prepared the rules for the installation of electrical apparatus known as the National Electrical Code, submitted a report which is contained in the *Transactions* of the American Society of Mechanical Engineers, Volume XIX., pages 33 and 984.

This code of rules was accepted and promulgated by the National Board of Fire Underwriters, and has continued in force, with such amendments being made at the annual meetings of the Underwriters' National Electric Association, as might be necessary to conform to the state of the art of the applications of electricity for lighting, transmission of power and signalling.

The rapid growth of electrical transmission of power was a subject of such importance, that the underwriters referred the matter to the code committee of the American Institute of Electrical Engineers, of which the writer is a member, but this code committee after preparing a draft of provisions intending to provide for the construction of these lines, especially in places where they approached to other classes of electrical lines or to buildings, considered the subject of too great importance to be settled by such a small number, and the National Conference on Standard Electrical Rules was assembled and held their meeting in Boston, March 24, 1903, at which the undersigned was a delegate representing the American Society of Mechanical Engineers.

At this meeting were representatives of the principal electrical and other technical societies, and also representatives of all types of electrical manufactures having an interest in this subject.

The following amendments to the National Electrical Code

* Appendix No. 2 to the Proceedings.

were adopted and have been accepted by the electrical committee of the underwriters and added to the 1903 edition of the Rules, which was issued June 1, 1903:

AMENDMENTS TO THE NATIONAL ELECTRICAL CODE.

12 A. Constant-Potential Pole Lines, Over 5,000 Volts.

(Overhead lines of this class unless properly arranged, may increase the fire loss from the following causes:

Accidental crosses between such lines and low-potential lines may allow the high-voltage current to enter buildings over a large section of adjoining country. Moreover, such high voltage-lines, if carried close to buildings, hamper the work of firemen in case of fire in the building. The object of these rules is so to direct this class of construction that no increase in fire hazard will result, while at the same time care has been taken to avoid restrictions which would unreasonably impede progress in electrical development.

It is fully understood that it is impossible to frame rules which will cover all conceivable cases that may arise in construction work of such an extended and varied nature, and it is advised that the Inspection Department having jurisdiction be freely consulted as to any modification of the rules in particular cases.)

(*a*) Every reasonable precaution must be taken in arranging routes so as to avoid exposures to contacts with other electric circuits. On existing lines, where there is a liability to contact, the route should be changed by mutual agreement between the parties in interest wherever possible.

(*b*) Such lines should not approach other pole lines nearer than a distance equal to the height of the taller pole line, and such lines should not be on the same poles with other wires, except that signalling wires used by the Company operating the high-pressure system, and which do not enter property other than that owned or occupied by such Company, may be carried over the same poles.

(*c*) Where such lines must necessarily be carried nearer to other pole lines than is specified in Section *b* above, or where they must necessarily be carried on the same poles with other wires, extra precautions to reduce the liability of a breakdown to a minimum must be taken, such as the use of wires of ample mechanical strength, widely spaced cross-arms, short spans, double or extra heavy cross-arms, extra heavy pins, insulators, and poles thoroughly supported. If carried on the same poles with other wires, the high-pressure wires must be carried at least three feet above the other wires.

(*d*) Where such lines cross other lines, the poles of both lines must be of heavy and substantial construction.

Whenever it is feasible, end-insulator guards should be placed on the cross-arms of the upper line. If the high-pressure wires cross below the other lines, the wires of the upper line should be dead-ended at each end of the span to double-grooved, or to standard transposition insulators, and the line completed by loops.

One of the following forms of construction must then be adopted:

(1) The height and length of the cross-over span may be such that the shortest distance between the lower cross-arms of the upper line and any wire of the lower line will be greater than the length of the cross-over span, so that a

wire breaking near one of the upper pins would not be long enough to reach any wire of the lower line. The high-pressure wires should preferably be above the other wires.

(2) A joint pole may be erected at the crossing point, the high-pressure wires being supported on this pole at least three feet above the other wires. Mechanical guards or supports must then be provided, so that in case of the breaking of any upper wire, it will be impossible for it to come into contact with any of the lower wires.

Such liability of contact may be prevented by the use of suspension wires, similar to those employed for suspending aerial telephone cables, which will prevent the high-pressure wires from falling, in case they break. The suspension wires should be supported on high potential insulators, should have ample mechanical strength, and should be carried over the high-pressure wires for one span on each side of the joint pole, or, where suspension wires are not desired, guard wires may be carried above and below the lower wires for one span on each side of the joint pole, and so spread that a falling high-pressure wire would be held out of contact with the lower wires.

Such guard wires should be supported on high-potential insulators or should be grounded. When grounded, they must be of such size, and so connected and earthed, that they can surely carry to ground any current which may be delivered by any of the high-pressure wires. Further, the construction must be such that the guard wires will not be destroyed by any arcing at the point of contact likely to occur under the conditions existing.

(3) Whenever neither of the above methods is feasible, a screen of wires should be interposed between the lines at the cross-over. This screen should be supported on high-tension insulators or grounded, and should be of such construction and strength as to prevent the upper wires from coming into contact with the lower ones. If the screen is grounded, each wire of the screen, and especially its ground connection, should have a current-carrying capacity greater than the current which may be delivered by any wire of the upper line, must be of such size and so connected and earthed that it can surely carry to ground any current which may be delivered by any of the high-pressure wires. Further, the construction must be such that the wires of screen will not be destroyed by any arcing at the point of contact likely to occur under the conditions existing.

(e) When it is necessary to carry such lines near buildings, they must be at such height and distance from the building as not to interfere with firemen in event of fire; therefore, if within twenty-five feet of a building, they must be carried at a height not less than that of the front cornice, and the height must be greater than that of the cornice as the wires come nearer to the building in accordance with the following table:—

Distance of wire from building.	Elevation of wire above cornice of building.
Feet.	Feet.
25	0
20	2
15	4
10	6
5	8
2½	9

It is evident that where the roof of the building continues nearly in line with the walls, as in Mansard roofs, the height and distance of the line must be reckoned from some part of the roof instead of from the cornice.

[AMENDMENT TO 13 A (b).]

(13 A) Grounding Low-Potential Circuits.

(*b*) Transforming secondaries of distributing systems should preferably be grounded, and when grounded, the following rules must be complied with:

(1) The grounding must be made at the neutral point or wire, whenever a neutral point or wire is accessible.

(2) When no neutral point or wire is accessible, one side of the secondary circuit may be grounded, provided, the maximum difference of potential between the grounded point and any other point in the circuit does not exceed 250 volts.

(3) The ground connection must be at the transformer as provided in sections *d*, *e*, *f*, *g*, and when transformers feed systems with a neutral wire, the neutral wire must also be grounded at least every 250 feet for overhead systems, and every 500 feet for underground systems.

Inspection Departments having jurisdiction may *require* grounding if they deem it necessary.

(AMENDMENT TO 64.)

(64) Signalling Systems.

(*a*) Outside wires should be run in underground ducts, or strung on poles, and as far as possible kept off of buildings, and must not be placed on the same cross-arms with electric light or power wires. *They * should not occupy the same duct, manhole or handhole of conduit systems with electric light or power wires.*

Single manholes, or handholes, may be separated into sections by means of partitions of brick or tile so as to be considered as conforming with the above rule.

Respectfully submitted,
C. J. H. WOODBURY.

* The Amendment consists of the words italicised.

No. 978.*

SECOND EDITION

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PROPOSED

CONSTITUTION, BY-LAWS AND RULES

REPORT OF

THE SPECIAL COMMITTEE

ON

RULES AND METHODS

* Appendix No. 3 to the Proceedings.

SECOND EDITION

REVISED JUNE 2d, 1903

NOTE:

This revised edition of the Draft of Constitution, By-Laws and Rules, incorporates desirable changes and amendments which have been submitted by members pursuant to the request of the President, and have been considered and accepted by the Committee previous to June 1st. The action of the Saratoga meeting will be based upon the revised draft presented herewith.

REPORT OF THE COMMITTEE.

At the Boston meeting of the American Society of Mechanical Engineers in June, 1902, a Special Committee on Rules and Methods was appointed to revise the present Rules of the Society, to consider the amendments that had been offered, and to report to the Society, in accordance with the following resolution: (*Transactions*, vol. 23, p. 413.)

Resolved, That this meeting appoint a Special Committee on Rules and Methods, which Committee shall take under advisement the whole subject of the Rules, By-Laws and business methods of the Society, including such changes or amendments as have been or may be proposed by members, and shall submit its conclusions and recommendations to the membership in a report which shall be delivered to the Secretary, and which the Secretary shall thereupon cause to be printed and distributed to the membership.

The Committee has proceeded upon the plan submitted in the report of the Finance Committee, and adopted by the Council at the Annual Meeting of 1901; namely that the Rules when amended should be divided into three divisions,—a Constitution which could be amended only after full deliberation and by letter-ballot;—By-Laws which could be more easily amended; and Rules which could be changed at any session of the Council. The Constitution in the present draft, contains the fundamental objects and functional organization of the Society. The By-Laws include the provisions for putting into practical execution the functions specified in the Constitution. The Rules have the same force as the By-Laws, but are subject to change at any time by the Council.

It is necessary to bear this division in mind in reading the draft herewith presented, because the same subject matter may be found in the Constitution in a broad sense, and the provisions for its execution in the By-Laws.

The present Rules of the Society were taken as a basis of this draft, and each paragraph assigned to the Constitution, the By-Laws or the Rules, as seemed appropriate. The Constitutional sections were combined, and such prefatory and connecting sentences added as were needed to make a first draft. When this had been accomplished, it was evident that many subjects had been taken as a matter of common understanding, and were not expressed in the Constitution; also that the wording of paragraphs was in some cases incomplete. When the draft had proceeded thus far, the Constitution and By-Laws of kindred Societies were consulted,—such as the Institution of Civil Engineers, the Institution of Mechanical Engineers, The Iron and Steel Institute of Great Britain, the American Society of Civil Engineers, American Institute of Mining Engineers, American Institute of Electrical Engineers, and such others as the Committee was able to consult. Various new provisions were found to be desirable.

The Committee would also report that it has given careful consideration to the amendments proposed at the meetings of the Society and referred to it by vote at the New York meeting. With respect to the proposition offered by Mr. Kent to increase the size of the Publication Committee to nine persons, it has been thought advisable to intrust the important work hitherto discharged by the Publication Committee, to ten persons, divided into two independent committees (C 45 and B 24 and 25), of which one shall be known as the Committee on Meetings and the other as the Publication Committee.

The work of the Committee on Meetings will be to procure papers and pass on their suitability for presentation, with power to refer any paper presented to persons especially qualified by theoretical knowledge or practical experience to advise concerning them. The other Committee, called the Publication Committee, acting independently of the Committee on Meetings will decide what papers or discussions, or parts of the same shall be printed in the *Transactions*.

It is thought that by these means the desired scrutiny of papers will be secured in advance of the meeting on the one hand, and on the other a careful examination insured after the meeting by a second committee, which has the power of rejection of unsuitable material in either papers or discussions.

The Committee has considered the carefully prepared adaptation by Mr. Gus C. Henning of the Rules of the Verein-Deutscher-Ingenieure to the conditions of this Society, and would call attention to several valuable details incorporated into the Constitution and By-Laws from this source (C 52); but it has not felt that so considerable a change in the methods and conduct of the Society as would follow from copying these precedents more closely would be either wise or acceptable at the present time.

In addition to the above, various provisions of the Corporation Law of the State of New York, under which the business proceedings of the Society must be conducted, have been added for convenience of reference. In order that attention may be directed at once to important sections, the following brief notes are submitted.

The numbered sections of the Constitution are preceded by the letter C; the By-Laws are designated by B, and the Rules by R.

CONSTITUTION.

C 1. Contains the official title of the Society, specified in its corporate organization. The precise title has been a subject of inquiry at times, hence it has been included in this section.

C 2. The change in the old Rule is the addition of "maintenance of an Engineering Library," in next to the last line.

C 3 and 4. Is a statement of some requirements of the Corporation Laws of the State of New York.

C 5. The wording has been changed to correspond with the objects of the Society as stated in C 2.

C 6 to 11. Are the same as the present Rules except that C 10 has the word "subordinate" added in next to the last line in order to make the difference between a Junior and an Associate a little more marked.

C 12. Is a new article from a kindred Society, which emphasizes the fact that it is a membership, and not a business corporation, and that a member, when leaving the Society, has no claim upon the assets of the Society.

C 16. Contains a change in the number of adverse votes necessary to defeat an election, and specific provisions in relation to the procedure for a second ballot.

C 21. Is a change from the present Rules to make the annual dues for a Junior after six years the same as those of an Associate. With the lower limit of Junior age fixed at 21, Juniors will be of Associate age in any case within six years. By permitting the Junior six years' membership at the low rate, it may be assumed that he will have reached a position at the end of this period when he can properly afford to pay the increased rate or will be in a position to be promoted to Associate membership by the usual process. If he is not promoted, his dues will be the same as in the Associate grade. The question of the proper amount of the dues for membership has not been considered by this committee to be a subject for its investigation.

C 22. Is intended to prevent a large influx of life members by placing the admission to this class in the discretion of the Council. It is also novel in making the amount that shall be paid for life membership depend on the age of the member, and specifies a definite mode of fixing the amount to be paid.

C 24 and 25. Are new sections, the substance of which is contained in some form by almost every Society. Our present Rules have no provision of any kind to relieve itself of members who have violated the Constitution or By-Laws of the Society.

C 26. This section includes five Past Presidents in the Council, each having full voting power. The American Institute of Electrical Engineers has three Past Presidents on the Council, and the American Society of Civil Engineers has five. Considering that Past Presidents of this Society usually live in widely separated places, it was thought that five would be a suitable number of which only one or two will usually be present at the Council meetings. It will be noted also that the Chairman of the Finance Committee under this provision will be expected to sit with the Council and advise it when financial questions are under consideration. The Council will have expert advice from this Committee when required. It will be apparent also that by this provision the Finance Committee is kept in close touch with the Council.

C 27. It is hoped that the Society may receive bequests as years go on. Hence, it is thought that a provision in the Constitution, stating that bequests shall be invested by the Council, and become a permanent fund, and not be used for current expenses, would commend itself to the favor of those who wish to make a bequest for the benefit of the Society.

C 28. Is a provision for filling vacancies in the Council in accordance with the corporation law of the State.

C 29. Specifies the procedure in case of the death of a Past President who was a member of the Council.

C 31. Is the law of the State of New York, quoted *verbatim* *et literatim* for convenient reference by the officials of the Society.

C 32. Is a By-Law from a kindred Society, which is intended to prevent vexatious discussions on past subjects.

C 36. States specifically when the official term of an officer shall commence, and also makes provision in case a candidate does not accept the office to which he has been elected.

C 45. Specifies the standing Committees of the Society. The duties of each of the Committees are specified in the By-Laws, and it will be noted in B 25—B 30 that one member on each of these Committees is appointed each year to serve 5 years. The Committees thus become continuous bodies, competent to carry out a definite policy in Society affairs. The Committee on Meetings (B 26) is a new Committee, and the Membership Committee (B 28) carries out the present practice of the Society under the existing Rule which was not heretofore specified.

C 49. Puts into the Constitution the present practice concerning Professional Committees.

C 52. Is a new section, authorizing sections or groups of the Society under such conditions as the Council may prescribe. This covers essentially an amendment proposed by Mr. Gus C. Henning, and also the present practice of the American Institute of Electrical Engineers. The section has been carefully drawn to place the management of these proposed sections entirely in the discretion and control of the Council.

C 56. Is a new section in relation to adoption by the Society of standards, and puts into the Constitution what has been the unvarying practice of the Society from its organization.

C 57 and 58. A form of procedure for amending the Constitution which requires one year.

C 59. Provides for amending the By-Laws requiring six months' consideration.

C 60. Refers to the Rules (C 3) which can be amended by the Council at any meeting.

B 21. By this provision the Committees are made responsible for the conduct and financial detail of their appropriate work. It is intended that the Executive Committee should take charge of detail which does not attach to the Standing Committees. It incorporates into the By-Laws a desirable method built up on the present practice.

B 23. By specifying monthly meetings of the Finance Committee that body should be in close touch with the work and needs of this Society during the year.

B 32. This provision affords a graceful method of representation at various functions by an official of the Society.

R 5, 6, and 8. It has been thought advisable to incorporate with some emphasis into the published Rules, the practice of the Society with respect to brief presentation of printed papers at the meetings. The Committee thinks that increased interest and discussion will both be secured by an enforcement of these provisions.

Respectfully submitted,

C. W. Hunt, Chairman
Jesse M. Smith
D. S. Jacobus
R. H. Soule
G. M. Basford

Special Committee on Rules and Methods.

INDEX

TO THE DRAFT OF THE

CONSTITUTION, BY-LAWS AND RULES.

AMERICAN SOCIETY MECHANICAL ENGINEERS.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

CONSTITUTION.

NAME, OBJECT AND GOVERNMENT.

C 1. The title of this Society is "The American Society of Mechanical Engineers."

C 2. The object of the Society is to promote the Arts and Sciences connected with Engineering and Mechanical Construction. The principal means for this purpose shall be the holding of meetings for the reading and discussion of professional papers, and for social intercourse; the publication and distribution of its papers and discussions; and the maintenance of an Engineering Library.

C 3. The Society shall be governed by this Constitution, and by By-Laws and Rules in harmony therewith.

C 4. The Society was organized as a Corporation under the laws of the State of New York, April 7, 1880. Its offices shall be located in the City of New York.

MEMBERSHIP.

C 5. Persons connected with the Arts and Sciences relating to Engineering or Mechanical Construction may be eligible for admission into the Society.

C 6. The membership of the Society shall consist of Honorary Members, Members, Associates and Juniors. Honorary Members, Members and Associates are entitled to vote and to hold office. Juniors shall not be entitled to vote nor to be officers of the Society, but shall be entitled to the other privileges of membership.

C 7. Honorary Members, Members and Associates are entitled to vote on all questions before any meeting of the Society, in person or by proxy, given to a voting member. A proxy shall not be valid for a greater time than six months.

C 8. Honorary Members shall be persons of acknowledged professional eminence, and their number shall not exceed twenty-five at any time.

C 9. A Member must have been so connected with Engineering as to be competent, as a designer or as a constructor, to take responsible charge of work in his branch of Engineering, or he must have served as a teacher of Engineering for more than five years. A Member shall be thirty years of age or over.

C 10. An Associate must either have the other qualifications of a Member or be so connected with Engineering as to be competent to take charge of engineering work, or to co-operate with Engineers. An Associate shall be twenty-six years of age or over.

C 11. A Junior must have had such engineering experience as will enable him to fill a responsible subordinate position in engineering work, or he must be a graduate of an engineering school. A Junior shall be twenty-one years of age or over.

C 12. The rights and privileges of every Honorary Member, Member, Associate and Junior shall be personal to himself, and shall not be transferable or transmissible by his own act or by operation of law.

ADMISSION.

C 13. Honorary Members shall be nominated by at least ten members of the Society. The grounds upon which the nomination is made, shall be presented to the Council in writing.

C 14. All applications for membership to the grades of Member, Associate or Junior shall be presented to the Council, which shall consider and act upon each application, assigning each approved applicant to the grade of membership to which, in the judgment of the Council, his qualifications entitle him. The name of each candidate thus approved by the Council, shall, unless objection is made by the applicant, be submitted to the voting membership for election, by means of a letter-ballot.

C 15. Associates or Juniors desiring to change their grade of membership shall make application to the Council in the same manner as is required in the case of a new applicant.

C 16. Election to membership shall be by a sealed letter-ballot as the By-Laws shall provide. Adverse votes to the number of two per cent. of the votes cast shall be required to defeat the election of an applicant for any grade of membership. The Council, may in its discretion, order a second ballot upon a defeated applicant, in which case adverse votes to the number of four per cent. of the votes cast, shall be required to defeat the election.

C 17. The election of Honorary Members shall be by a vote of the Council taken by letter-ballot, as provided in the By-Laws. One dissenting vote shall defeat such election.

C 18. Each person elected, excepting Honorary Members, shall subscribe to this Constitution, and shall pay the initiation fee before he can be entitled to the rights and privileges of membership. If such person does not comply with this requirement within six months after notice of his election, he will be deemed to have declined election. The Council may, thereupon, declare his election void.

INITIATION FEES AND DUES.

C 19. The initiation fee for membership in each grade shall be as follows:

For Member.................Twenty-five Dollars,
For Associate................Twenty-five Dollars,
For Junior...................Fifteen Dollars.

C 20. A Junior, on promotion to any other grade of membership, shall pay an additional fee of Ten Dollars.

C 21. The annual dues for membership in each grade shall be as follows:

For Member.....................Fifteen Dollars,
For Associate....................Fifteen Dollars,
For Junior.................Ten Dollars for the first six years of his membership and thereafter the same as for an Associate.

C 22. The Council may in its discretion, permit any Member or Associate to become a Life Member in the same grade, by the payment at one time of an amount sufficient to purchase from the Equitable Life Assurance Society of New York, an annuity on the life of a person of the age of the applicant equal to the annual dues in his grade. Such Life Member shall not be liable thereafter for annual dues.

C 23. The Council shall have the power, by letter-ballot, to admit to Life Membership, without the payment of a life membership fee, any person who, for a long term of years, has been a Member or an Associate when, for special reasons, such procedure would, in its judgment, promote the best interests of the Society, provided that notice of such proposed action shall have been given at a previous meeting of the Council. One dissenting vote shall defeat such admission.

SUSPENSIONS AND EXPULSIONS.

C 24. Any Member, Associate or Junior who shall leave his annual dues unpaid for one year, shall not receive the volume of *Transactions* until such arrears are paid. Any Member, Associate or Junior who shall leave his dues unpaid for two years, shall, in the discretion of the Council, have his name stricken from the roll of membership, and shall cease to have any further rights as such.

C 25. The Council may refuse to receive the dues of any member of any grade, who shall have been adjudged by the Council to have violated the Constitution or By-Laws of the Society, or who, in the opinion of the Council by a two-thirds vote, shall have been guilty of conduct rendering him unfit to continue in its membership; and the Council may expel such person and remove his name from the list of members.

THE COUNCIL.

C 26. The affairs of the Society shall be managed by a Board of Directors chosen from among its Members and Associates, which shall be styled "The Council." The Council shall consist of the President of the Society, who shall be the presiding officer, six Vice-Presidents, nine Managers, the Treasurer and five Past Presidents. Five members of the Council shall constitute a quorum for the transaction of business. The Secretary may take part in the deliberations of the Council, but shall not have a vote therein. The Chairman of the Finance Committee shall attend the meetings of the Council and take part in the discussion of financial questions but shall not have a vote.

C 27. The five surviving Past Presidents who last held the office shall be members of the Council with all the rights, privileges and duties of the other members of the Council.

C 28. The Council thus constituted shall be the legal Trustee of the Society. All gifts or bequests not designated for a specific purpose shall be invested by the Council, and only the income therefrom may be used for current expenses.

C 29. Should a vacancy occur in the Council, or in any elective office except the presidency, through death, resignation or other cause, the Council may elect a Member or Associate to fill the vacancy until the next annual election.

C 30. The Council shall regulate its own proceedings, and may by resolution delegate specific powers to an Executive Committee or to any one or more members of the Council. No act of the Executive Committee or of a delegate shall be binding until it has been approved by a resolution of the Council.

C 31. The Council shall present at the Annual Meeting of the Society a report verified by the President or Treasurer or by a majority of the members of the Council, showing the whole amount of real and personal property owned by the Society, where located, and where and how invested, and the amount and nature of the property acquired during the year immediately preceding the date of the report, and the manner of the acquisition; the amount applied, appropriated or expended during the year immediately preceding such date, and the purposes, objects or persons to or for which such applications, appropriations or expenditures have been made; also the names and places of residence of the persons who have been admitted to membership in the Society during the last year, which report shall be filed with the records of the Society, and an abstract thereof shall be entered in the minutes of the proceedings of the Annual Meeting.

C 32. An act of the Council, which shall have received the expressed or the implied sanction of the membership at the next subsequent meeting of the Society, shall be deemed to be the act of the Society, and shall not afterwards be impeached by any member.

C 33. The Council may, by a two-thirds vote of the members present, declare any elective office vacant, on the failure of its incumbent for one year, from inability or otherwise, to attend the Council meetings, or to perform the duties of his office, and shall thereupon appoint a Member or Associate to fill the vacancy until the next Annual Meeting. The said appointment shall not render the appointee ineligible to election to any office.

OFFICERS.

C 34. At each Annual Meeting there shall be elected from among the Members and Associates:

A President to hold office for one year.

Three Vice-Presidents, each to hold office for two years.

Three Managers, each to hold office for three years.

A Treasurer to hold office for one year.

C 35. The election of officers shall be by sealed letter-ballot, as the By-Laws shall provide.

C 36. The term of all elective officers shall begin on the adjournment of the Annual Meeting of the Society. Officers shall continue in their respective offices until their successors have been elected and have accepted their offices.

C 37. A President, Vice-President or Manager shall not be eligible for immediate re-election to the same office at the expiration of the term for which he was elected.

C 38. The Council, at its first meeting after the Annual Meeting of the Society, shall appoint a person of the grade of Member to serve as Secretary of the Society for one year, subject to removal for cause by an affirmative vote of fifteen members of the Council, at any time after one month's written notice has been given him to show cause why he should not be removed, and he has been heard in his own defense, if he so desires. The Secretary shall receive a salary which shall be fixed by the Council at the time of his appointment.

C 39. The President, Secretary and Treasurer shall perform the duties legally or customarily attaching to their respective offices under the Laws of the State of New York, and such other duties as may be required of them by the Council.

C 40. A vacancy in the office of President shall be filled by the Vice-President, who is senior by age.

MEETINGS.

C 41. The Society shall hold two meetings in each year. The Annual Meeting shall begin in New York City on the first Tuesday in December, and a Semi-Annual Meeting shall be held at such time and place as the Council may appoint. Fifty Members and Associates shall constitute a quorum for the transaction of business.

C 42. Special meetings of the Society may be called at any time at the discretion of the Council, or shall be called by the President upon the written request of fifty members entitled to vote, the notices for such meetings to state the business for which such meeting is called, and no other business shall be entertained or transacted at that meeting.

C 43. Any appropriation recommended by the Society at a meeting shall not take effect until it has been approved by the Council.

C 44. Every question which shall come before a meeting of the Society or of the Council or a Committee, shall be decided by a majority of the votes cast, unless otherwise provided in this Constitution or the By-Laws, or the Laws of the State of New York. The Council may order the submission of any question to the membership for discussion by letter-ballot. Any meeting of the Society at which a quorum is present, may order the submission of any question to the membership for discussion by letter-ballot.

STANDING COMMITTEES.

C 45. The Standing Committees of the Society to be appointed by the President shall be:

Finance Committee,
Committee on Meetings,
Publication Committee,
Membership Committee,
Library Committee,
House Committee.

C 46. There shall be a John Fritz Medal Committee of three members appointed as provided in the By-Laws.

C 47. The Annual Committees shall be:

An Executive Committee, appointed by the Council.

A Nominating Committee, appointed by the President.

Tellers as required by the By-Laws, appointed by the President.

C 48. Special Nominating Committee:

Twenty or more members entitled to vote may constitute themselves a Special Nominating Committee, with the same powers as the Annual Nominating Committee.

C 49. Professional Committees:

The Council shall have power to appoint, upon a recommendation of the Society at a general meeting, or upon its own initiative, such Professional Committees as it may deem desirable, to investigate, consider and report upon subjects of engineering interest. Reports of such committees may be accepted by the Society and printed in the *Transactions*, but shall not be approved or adopted as the action of the Society. Any proposed expenses of such committees must be authorized by the Council before they are incurred.

C 50. Each Committee shall perform the duties required of it in the By-Laws, or assigned to it by the Council. The Secretary of the Society shall be the Secretary of each of the Standing Committees.

C 51. The Council may at any time, in its own discretion, remove any or all members of any Committee, except a Nominating Committee; and the vacancy, arising from this or from any other cause, shall be filled by appointment by the President, except a vacancy in the Executive Committee, which shall be filled by the Council.

SECTIONS OF THE SOCIETY.

C 52. The Council may, in its discretion, authorize the organization of sections or groups of any or all grades of membership, for professional or scientific purposes which are in harmony with the Constitution and By-Laws of this Society. Such sections or groups may, in the discretion of the Council, be geographical or professional, and shall have such powers, and act under such rules and regulations as the Council may from time to time prescribe.

TRANSACTIONS.

C 53. The official record of technical papers and discussion, shall be known as the *Transactions* of the Society, and shall be published under the direction of the Council. There may be included therein, the annual report of the Council, reports of Committees, and business records of the Society.

C 54. The Society shall claim no exclusive copyright to any papers read at its meetings, or any reports or discussions thereon, except in the matter of their official publication under the Society's imprint as its *Transactions*. The policy of the Society shall be to give the professional and scientific papers read before it the widest circulation possible, with the view of making the work of the Society known, encouraging Engineering progress and extending the professional reputation of its members.

C 55. The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings. Matters relating to politics or purely to trade shall not be discussed at a meeting of the Society, nor be included in the *Transactions*.

C 56. The Society shall not approve or adopt any standard or formula, or approve any engineering or commercial enterprise. It shall not allow its imprint or name to be used in any commercial work or business.

AMENDMENTS TO THE CONSTITUTION.

C 57. At any semi-annual meeting of the Society any member may propose in writing an amendment to this Constitution. Such proposed amendment shall not be voted on at that meeting, but shall be open to discussion and to such modification as may be accepted by the proposer. The proposed amendment shall be mailed in printed form by the Secretary to each member of the Society entitled to vote, at least sixty days previous to the next annual meeting, accompanied by comment by the Council, if it so elects. At that annual meeting such proposed amendment shall be presented for discussion and final amendment, and shall subsequently be submitted to all members entitled to vote, provided that twenty votes are cast in favor of such submission. The final vote on adoption shall be by sealed letter-ballot, closing at twelve o'clock noon on the first Monday of March following.

C 58. The letter-ballot, accompanied by the text of the proposed amendment, shall be mailed by the Secretary to each member of the Society entitled to vote at least thirty days previous to the closure of the voting. The ballots shall be voted, canvassed and announced as provided in the By-Laws. The adoption of the amendment shall be decided by a majority of the votes cast. An amendment shall take effect on the announcement of its adoption by the Presiding Officer of the semi-annual meeting next following the closure of the vote.

AMENDMENTS TO BY-LAWS AND RULES.

C 59. For the further ordering of the affairs of the Society, the Council may, by a two-third vote of its members present, amend the By-Laws in harmony with this Constitution, provided that a written notice of such proposed amendment shall have been given at the previous regular meeting of the Council; and provided further that the Secretary shall have mailed to each member of the Council a copy of such proposed amendment, at least thirty days in advance of the meeting of the Council at which action is to be taken. The amendment shall take effect immediately on its passage by the Council. The Secretary shall at once mail a copy of such amendment to the members of all grades.

C 60. The Council may, by a majority vote of the members present at any meeting, establish, amend or annul Rules for the conduct of the business affairs of the Society; for the ordering and conduct of its professional or business meetings; and for guidance of its committees in their work and reports; provided that such Rules are in harmony with the Constitution and By-Laws of the Society.

CONSTITUTION GOES INTO EFFECT.

C 61. This Constitution shall supersede all previous Rules of the Society, and shall go into effect on the announcement by the Presiding Officer of its adoption.

BY-LAWS.

CANDIDATES FOR MEMBERSHIP.

B 1. A candidate for admission to the Society as a Member or as an Associate must make application on a form approved by the Council, upon which he shall write a statement giving a complete account of his qualifications and engineering experience, and an agreement that he will, if elected, conform to the Constitution, By-Laws and Rules of the Society. He must refer to at least five Members or Associates to whom he is personally known.

B 2. Applications for membership from Engineers who are not resident in the United States or Canada, and who may be so situated as not to be personally known to five Members of the Society, as required in the foregoing paragraph, may be recommended for ballot by five members of the Council, after sufficient evidence has been secured to show that in their opinion the applicant is worthy of admission to the grade which he seeks.

B 3. A candidate for admission to the Society as a Junior must make application in the same manner as provided for Members, except that he must refer to not less than three Members or Associates to whom he is personally known.

B 4. References shall not be required of candidates for Honorary Membership.

B 5. The references for each candidate for admission to the Society shall be requested to make a confidential communication to the Membership Committee, setting forth in detail such information, personally known to referee, as shall enable the Council to arrive at a proper estimate of the eligibility of the candidate for admission to the Society.

ELECTION OF MEMBERS.

B 6. The Secretary shall mail to each member entitled to vote, at least thirty days in advance of each annual or semi-annual meeting, a ballot stating the names and the respective grades of the candidates for membership in the Society which have been approved by the Council, and the time of the closure of voting. The voter shall prepare his ballot by crossing out the names of candidates rejected by him, and shall enclose said ballot in a sealed blank ballot envelope which he shall then enclose in a second sealed outer envelope on which he shall, for identification, write his name in ink. The ballot thus prepared and enclosed shall be mailed or delivered unopened to the Tellers of Election. The Secretary shall certify to the competency, and the signature of all voters. On the closure of voting, the Tellers of Election shall first open and destroy the outer envelopes, and shall then canvass the ballots, and certify the result to the meeting of the Society.

B 7. The Tellers shall not receive any ballot after the stated time of the closure of voting. A ballot without the endorsement of the voter, written in ink on the outer envelope, is defective, and shall be rejected by the Tellers of Election.

B 8. The names of those persons elected to membership, with their respective grades, shall be embodied in a written report, signed by the Tellers, and presented to the next meeting of the Society. The President shall then declare them duly elected to membership in the Society. The Tellers may, through the Secretary, in advance of any meeting advise each candidate of the result of the canvass of the votes in his case. The names of applicants who are not elected shall neither be announced nor recorded in the *Transactions*.

B 9. The endorsers of an applicant who has not been elected, may, with his consent, present to the Council a written request for a re-submission of his name to ballot. The Council may, in its discretion, by a three-fourths vote of the members present, order the name of the applicant placed on the next ballot for members.

B 10. Election to Honorary Membership shall be by letter-ballot of the Council. A notice of such proposed election shall be mailed by the Secretary to each member of the Council at least sixty days in advance of the date set for the closure of such election.

B 11. Each person elected to membership, except an Honorary Member, must subscribe to the Constitution, By-Laws and Rules of the Society, and pay the initiation fee before he can receive a certificate of membership in the Society.

ELECTION OF OFFICERS.

B 12. The Secretary shall mail to each member entitled to vote, at least thirty days before the Annual Meeting, the names of the candidates for office proposed for election by the Nominating Committee.

B 13. The names of the candidates proposed by the Nominating Committee or Committees, and the respective offices for which they are candidates, shall be printed in separate lists on the same ballot sheet, each list of candidates to be printed under the names of the members of the particular committee which proposed it.

B 14. The name of any candidate on the ballot may be erased, and the name of any person qualified to hold the office written in its stead. The voter shall make a cross with a pen or pencil before the name of each candidate for office for whom he wishes to vote. The ballot thus prepared must be voted and canvassed in the same manner as for the election of members.

B 15. At the first session of the Annual Meeting, the Tellers of Election of Officers shall canvass the votes cast for the officers of the Society in the manner prescribed for the election of members, and immediately report the result of the canvass to the meeting. The President shall then announce the candidates having the greatest number of votes for their respective offices, and declare them elected for the ensuing year.

B 16. In case of a tie in the vote for any officer, the President or, in his absence, the Presiding Officer shall cast the deciding vote.

B 17. A ballot which contains more names marked by a cross on it than there are officers to be elected, is thereby defective, and shall be rejected by the Tellers.

FEES AND DUES.

B 18. The initiation fee and annual dues of the first year shall be due and payable on notice of election to membership, and upon that payment the member will be entitled to the *Transactions* for the year. Thereafter the annual dues shall be due and payable on the first day of October in each year.

B 19. A member in arrears for one year shall not be entitled to vote until such arrears have been paid. Should the right to vote be questioned, the books of the Society shall be conclusive evidence.

B 20. The Secretary shall present to the Council the name of any Member, Associate or Junior in arrears for more than one year, and such member shall not receive the *Transactions* until such arrears are fully paid. A person dropped from the rolls for non-payment of dues may, in the discretion of the Council, be restored to the privileges of membership, upon payment of all arrears.

FINANCIAL ADMINISTRATION.

B 21. The Council at its first meeting in each fiscal year, shall consider the recommendations of the Finance Committee concerning the expenditure necessary for the work of the Society during that year. The apportioning of the work of the Society among the various Standing and other Committees shall be on a basis approved by the Council and in harmony with the Constitution and By-Laws. The appropriations approved by the Council, or so much thereof as may be required for the work of the Society, shall be expended by the various Committees of the Society, and all bills against the Society for such expenditure shall be certified by the Committee making the expenditure and shall then be sent to the Finance Committee for audit. Money shall not be paid out by any officer or employee of the Society except upon bills duly audited by the Finance Committee, or by resolution of the Council.

COMMITTEES.

B 22. The President within one month after the Annual Meeting shall fill all vacancies in the Standing Committees by appointment from the membership of the Society.

Each of the Standing and the Annual Committees, shall, at their first meeting after the Annual Meeting, elect a Chairman to serve for one year. The President shall appoint the Chairman of each Professional Committee. A member of a Standing Committee whose term of office has expired, shall continue to serve until his successor shall have been appointed.

FINANCE COMMITTEE.

B 23. The Finance Committee shall consist of five Members or Associates. The term of office of one member of the Committee shall expire at the end of each Annual Meeting. This Committee shall, in the discretion of the Council, have a supervision of the financial affairs of the Society, including the books of account. The Committee may cause the accounts of the Society to be audited and approved annually by a chartered or other competent public accountant. The Committee shall hold monthly meetings for the audit of bills and such other business as shall come before it and shall deliver to the Secretary for presentation to the Council at the end of each fiscal year, a report of the financial condition of the Society for the past year, and also shall present therewith a detailed estimate of the probable income and expenditure of the Society for the following twelve months. It shall make recommendations to the Council as to investments, and, when called upon by the Council, advise upon financial questions.

COMMITTEE ON MEETINGS.

B 24. The Committee on Meetings shall consist of five persons who may be members of any grade. The term of office of one member of the Committee shall expire at the end of each Annual Meeting. It shall be the duty of the Committee to procure professional papers, to pass upon their suitability for presentation, and to suggest topical subjects for discussion at the meetings. The Committee may refer any paper presented to the Society to a person or persons, especially qualified by theoretical knowledge or practical experience, for their suggestions or opinions as to the suitability of the paper for presentation. Papers from non-members shall not be accepted except by unanimous vote of the Committee.

The Committee shall arrange the programme of each meeting of the Society, and shall have general charge of the entertainments to be provided for the members and guests at each meeting. It shall prohibit the distribution or exhibition at the headquarters or at the meeting places of the Society of all advertising circulars, pamphlets or samples of commercial apparatus or machinery. At the end of each fiscal year, the Committee shall deliver to the Secretary for presentation to the Council, a detailed report of its work.

PUBLICATION COMMITTEE.

B 25. The Publication Committee shall consist of five Members or Associates. The term of office of one member shall expire at the end of each Annual Meeting. The Committee shall review all papers and discussions which have been presented at the meetings, and shall decide what papers or discussions, or parts of the same, shall be printed in the *Transactions* of the Society. The Committee will be expected to publish all such data as will be of assistance to engineers or investigators in their work. At the end of each fiscal year, the Committee shall deliver to the Secretary for presentation to the Council, a detailed report of its work.

MEMBERSHIP COMMITTEE.

B 26. The Membership Committee shall consist of five Members or Associates. The term of office of one member of the Committee shall expire at the end of each Annual Meeting. It shall be the duty of this Committee:

To meet monthly to receive and scrutinize all applications for membership to the Society.

To send to each voting member the name, qualifications, engineering experience and references of each applicant, together with extracts from the Constitution and By-Laws relating to membership.

To seek further information as to the qualifications of an applicant, whose evidence of eligibility is not clear to the Committee.

To report to each session of the Council the names of all applicants under consideration together with the action of the Committee on each.

The Committee shall at once destroy all correspondence in relation to each applicant when his name has been placed on the ballot by order of the Council, or upon the withdrawal of the application.

LIBRARY COMMITTEE.

B 27. The Library Committee shall consist of five Members, Associates or Juniors. The term of office of one member of the Committee shall expire at the end of each Annual Meeting. It shall be the duty of the Library Committee to take charge of the Library of the Society, the historical relics, the paintings and objects of art, and to recommend to the Council suitable regulations for their care and use. At the end of each fiscal year, the Committee shall deliver to the Secretary, a detailed report of its work.

HOUSE COMMITTEE.

B 28. The House Committee shall consist of five Members, Associates or Juniors. The term of office of one member of the Committee shall expire at the end of each Annual Meeting. It shall be the duty of the House Committee to have the care, management and maintenance of the house of the Society and its furnishings. They may make rules for the care and the use of the Society House, subject to the approval of the Council. At the end of each fiscal year, the Committee shall deliver to the Secretary a detailed report of its work.

EXECUTIVE COMMITTEE.

B 29. The Council shall appoint from its members an Executive Committee to act for the Council during the interval between its sessions. The Committee shall make a report of its acts to each session of the Council for approval. The Secretary may take part in the deliberations of the Executive Committee, but shall not have a vote therein.

NOMINATING COMMITTEES.

B 30. A Nominating Committee of five Members, not members of the Council, shall be appointed by the President within three months after he assumes office. It shall be the duty of this Committee to send to the Secretary on or before October first the names of consenting nominees for the elective offices next falling vacant under the Constitution. Upon the request of any Member or Associate, the Secretary shall furnish to the applicant the names of such nominees.

B 31. A special Nominating Committee if organized, shall, on or before October twentieth, present to the Secretary the names of the candidates nominated by it for the elective offices next falling vacant under the Constitution, together with the written consent of each.

JOHN FRITZ MEDAL COMMITTEE.

B 32. The John Fritz Medal Committee shall consist of three persons of the grade of Member, to be appointed by the Council. The term of office of one member of this Committee shall expire at the end of each annual meeting. The duty of this Committee shall be to represent the Society in the Board of Trustees of the John Fritz Medal Fund Corporation.

REPRESENTATIVE DELEGATES.

B 33. The Council may in its discretion appoint a member or members of the Society or other person or persons to represent it at meetings of Societies of kindred aim or at public functions. Such delegates shall be designated as "Honorary Vice-Presidents," and their duties shall terminate with the occasion for which they were appointed.

TELLERS.

B 34. The Presiding Officer shall, at the first session of the Annual Meeting, appoint three Tellers of Election of officers, whose duties shall be to canvass the votes cast, and report the result to the meeting. Their term of office shall terminate when their report of the canvass is presented to the meeting.

B 35. The President within one month after assuming office shall appoint three Tellers of Election of members to serve for one year, whose duties shall be to canvass the votes cast for members during the year, and to certify the same to the President. They shall notify candidates through the Secretary of the result of such election.

B 36. The President shall appoint three Tellers to canvass any letter-ballots which shall be ordered by the Council or by the Society.

MEETINGS.

B 37. The meetings of the Society shall continue from day to day as the meeting may decide. The business session of the Annual Meeting shall be held on Wednesday following the first Tuesday of December. The professional sessions for the reading of papers shall be held at such times and places as the meeting may appoint. Notices of all meetings of the Society shall be mailed by the Secretary to members of all grades not less than thirty days before the date of such meeting.

SECRETARY.

B 38. The Secretary of the Society shall be the Secretary to the Council and also to each of the Standing Committees.

The Secretary shall, under the supervision of the Finance Committee, have charge of the Books of Account of the Society.

He shall make and collect all bills against members or others.

He shall have charge of all bills against the Society, shall keep an account of the same, and shall present them in proper form to the Finance Committee for audit.

All funds received by any person for the Society, shall be delivered to the Secretary. He shall immediately enter them in the Books of Account, and shall immediately deposit such funds as he receives, to the credit of the Society, in a Bank to be designated by the Council.

TREASURER.

B 39. The Treasurer shall make payments only on the audit of the Finance Committee, or upon the direction of the Council, by resolution of that body. He shall furnish a bond for the faithful performance of his duties to such amount as the Council may require, such bond to be procured from an incorporated Guarantee Company, at the expense of the Society.

TITLES, EMBLEMS, CERTIFCATE.

B 40. Each Member and Associate shall, subject to such rules as the Council may establish, be entitled on request, to a certificate of membership, signed by the President and Secretary of the Society. Every such certificate shall remain the property of the Society, and shall be returned to it on demand of the Council.

B 41. Each proxy authorizing a person to vote for an absent member, shall be signed by such absent member, with an attesting witness, and be submitted to the Secretary for verification of the member's right to vote at the meeting at which the right is to be exercised.

B 42. The emblem of each grade of membership approved by the Council shall be worn by those only who belong to that grade. The official stationary shall be used only by Officers and Committees of the Society.

B 43. The abbreviation of the titles of the various grades of membership approved by the Society are as follows:

For Honorary Members, . .	Hon. Mem. Am. Soc. M. E.
For Members, ...	Mem. Am. Soc. M. E.
For Associates, ...	Assoc. Am. Soc. M. E.
For Juniors, ...	Jun. Am. Soc. M. E.

RULES.

R 1. The Secretary's office shall be open on business days from 9 A.M. to 5.30 P.M. During the Annual Meeting, the office shall be open from 9 A.M. to 10 P.M. A register shall be kept for each regular meeting, to record the attendance of members and guests.

R 2. The Secretary shall provide a numbered badge or pin for each member or guest attending the regular meetings, the number on the badges to correspond with the member's of guest's number on the register.

R 3. The Secretary shall at each regular meeting of the Society distribute at the headquarters a printed list of the names registered at the meeting.

R 4. Copies of papers to be read and discussed at any meeting shall be sent to each member thirty days in advance of that meeting. A paper received too late for such distribution shall only be accepted for presentation at that meeting by unanimous consent of the Committee on Meetings. A blank shall accompany the papers by which a member may signify his intention to discuss any of the papers, and priority in debate shall be given in the order of the receipt by the Secretary of such notification.

R 5. At professional sessions, each paper shall be read by abstract only, ten minutes being allowed to the author for the presentation, unless otherwise ordered by the meeting.

R 6. A member who has given notice of his intention to discuss a paper, and shall have reduced his discussion to writing, shall be entitled to ten minutes for its presentation.

R 7. Each speaker shall be limited to five minutes in the oral discussion of a paper, unless the time should be extended by unanimous consent. A member who has once had the floor cannot claim it again until all the others have been heard who desire to speak on that paper. Authors may have five minutes to close the discussion on the paper.

R 8. Members unable to attend the meeting may send a discussion of any paper in writing, to be presented by the Secretary.

R 9. The Committee on Meetings shall deliver to the Secretary such papers as they recommend for presentation to the professional meetings of the Society.

R 10. The Secretary shall have sole possession of papers and illustrations between the time of their approval by the Committee on Meetings, and their presentation to the professional session of the Society.

R 11. After the presentation and discussion of a paper, a copy of both shall be sent to the author, and, so far as possible, a copy of the reported discussion shall be sent to each member who presented it, with the request that he correct errors or omissions, and return the same promptly to the Secretary.

R 12. Members may order reprints of papers at a price sufficient to cover the cost to the Society, provided that said copies are not for sale.

R 13. The Secretary may furnish to the author twenty copies of his paper without charge. He may also furnish to the technical press such papers in advance of the meeting as they may wish to publish after presentation to the meeting of Society.

R. 14. The entertainments to be provided for the members and guests at any meeting of this Society in any city shall be in charge of a Local Committee, subject, however, to the general approval of the Committee on Meetings.

R 15. A member may invite a non-member to the professional sessions of the meeting, but the guest shall not take part in the proceedings without an invitation from the Presiding Officer. Invitations to guests of members for the entertainments provided for the Society shall be in the discretion of the Local Committee.

R 16. The Society House shall be open at all hours for access to members. The Library shall be open on all week days between the hours of 10 o'clock A.M. and 10 o'clock P.M. It shall be conducted as a Free Public Reference Library of Engineering and the Allied Arts and Sciences.

R 17. Juniors who were elected to membership in the Society six years or more previous to the adoption of this Constitution, shall pay the same dues as an Associate, beginning with the fiscal year which opens after such adoption. Juniors, who have been elected less than six years before that date, shall pay the dues of an Associate on the expiration of six years after their election.

No. 979.*

SPECIFICATIONS FOR BOILER PLATE, RIVET STEEL, STEEL CASTINGS AND STEEL FORGINGS.

Professor Spangler.—You may remember the conditions under which this Committee was appointed, but to make it entirely clear I would like to go into the history of it just a little. There is a society known as the American Society for Testing Materials, which was the outgrowth of the International organization of which we have heard a great deal at meetings of this Society. Committees No. 1 of that Society prepared a series of specifications, and Mr. Webster, at the request of Mr. Hutton, presented these specifications at a meeting of this Society, and asked that a committee be appointed on this particular subject. A committee of five was appointed, consisting of Mr. Cramp, Mr. Kent, Mr. Morison, Mr. Waitt and myself. In the usual way copies of these specifications were sent to various members of the Society, with the usual result—that is, in a few cases, after writing two or three letters, replies were received. The Committee decided to submit, at this time, a report to the Society, subject to revision, asking that the report be sent to all members of the Society, that something like a full written discussion from members who are interested in the subject might be had, and that a revised report be formulated at some future time.

It seems to me to be the proper procedure that, after this Society has finished whatever work it may decide to do, the report, together with the report of all the committees of other societies that may be working on the subject, should go back to Committee No. 1—that is, any report that we might make should be rather an advisory report than an attempt at a finality. This Committee No. 1 is the Committee which will finally, I believe, formulate specifications under which work of this sort is to be done.

With this as an introduction, your Committee would respectfully report as follows:

---

* Appendix No. 4 to the Proceedings.

SPECIFICATIONS FOR BOILER PLATE, RIVET STEEL, STEEL CASTINGS AND STEEL FORGINGS.

This report is sent out subject to revision, and the Committee asks that written discussion be sent to its chairman that the results may be incorporated in the final report to be presented at the New York meeting of the Society.

The Committee to which was referred the question of specifications for boiler plate, rivet steel, steel castings and steel forgings, reports that it has used the specifications prepared by the American Branch of Committee No. 1 of the International Association for Testing Materials, of which Mr. Wm. R. Webster is Chairman, as the basis of its work, and the changes hereafter noted are recommended in these specifications.

1. That the maximum sulphur in flange or boiler steel be reduced from .05 to .04.

2. That the tensile strength be specified as stated in the table with an allowable variation of 5,000 pounds. That fire box steel be specified at 55,000 pounds instead of 57,000 pounds per square inch. That the determination of the yield point for ordinary grades be omitted.

3. The tensile strength of castings has been modified, the specified value desired being stated, and the variation, 5,000 pounds, being allowed. The values, as recommended by Committee No. 1, and by this Committee, are as follows:—

	Com. No. 1's. Minimum.	Recommended by Committee.
Soft	60,000	60,000 ± 5,000
Medium	70,000	70,000 ± 5,000
Hard	85,000	80,000 ± 5,000

4. The elongation in 8″ is stated instead of in 2″ and an increase in elongation of 25% is called for on the 2″ specimen.

For a 2″ specimen from castings the corresponding elongations are:

	Com. No. 1.	Recommended by this Committee.
Soft	22%	20%
Medium	18%	17.5%
Hard	15%	15%

5. That the 8″ specimen be made the standard specimen and the 2″ to be used only when it is inconvenient to use the 8″.

6. That nickel steel forgings and oil tempered forgings be not included in this specification, because the present state of the art does not warrant general specifications being drawn for these materials.

7. That for soft or low carbon steel forgings the chemical requirements be not over .06 phosphorous, and .05 sulphur, instead of .10 phosphorous and .10 carbon.

8. That for "carbon steel not annealed" the term "medium steel" be used, and that the sulphur be reduced from .06 to .05 per cent.

9. That, wherever it is desirable that the elastic limit be determined, an extensometer be used, and that the elastic limit be taken as "that point at

which the elongation in 8" per 1,000 pounds of added stress per square inch first exceeds four ten-thousandths of an inch." *

10. The remainder of the specifications of Committee No. 1 are recommended for adoption, and are here re-arranged.

Standard Specifications for Steel Boiler Plate, Rivets, Castings and Forgings.

Process of Manufacture.

Boiler Plate and Rivet Steel shall be made by the open hearth process.

Castings and Forgings are to be made by the open hearth, crucible, or Bessimer process.

Castings are to be annealed or unannealed as specified.

Tensile Tests.

Test piece—The standard test specimen shall be eight inches (8") gauged length. The standard shape is shown in Fig. 145.

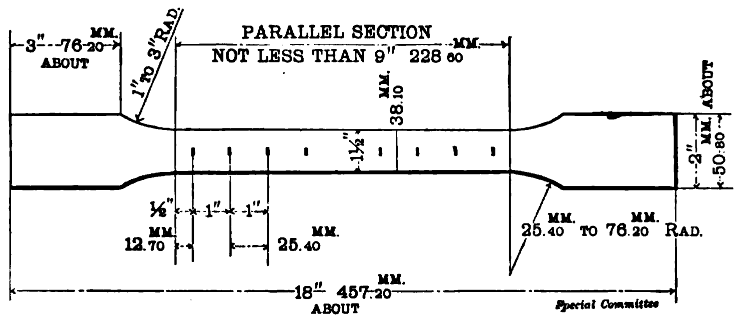


Fig. 145.

Width of specimen along the parallel section shall be 1½ inches, whenever possible.

Thickness of specimen shall be one-half inch or over, whenever possible.

Plates—Two opposite sides shall be the rolled surfaces if not over ¾-inch thick.

Rivets—Rivet rounds and small rolled bars shall be tested full size as rolled.

Castings and Forgings—Specimen may be planed parallel sided or turned parallel for not less than 9 inches in length, the smallest dimension being ½-inch, if possible.

When it is inconvenient to use the standard test specimen the specimen may be made as shown in Fig. 146. In every such specimen the elongation in two inches will be 25% greater than that specified for the standard specimen.

Number of Test Specimens.

If a tensile specimen develops flaws or breaks outside the middle third of its gauged length, another may be substituted.

* The "apparent elastic limit," suggested by Prof. J. B. Johnson and restated by Kent in *Transactions of Mining Engineers*, 1903.

Plates—One from each plate as it is rolled.

Rivet Rounds.—Two from each melt.

Castings and Forgings—Depending upon the character and importance of the piece.

Location of Test Specimens.

Castings—A test piece shall be cut cold from a coupon to be molded and cast on some portion of one or more castings from each melt or blow, or from the sink-heads (in case heads of sufficient size are used.) The coupon or sink-head must receive the same treatment as the casting or castings, before the specimen is cut out, and before the coupon or sink-head is removed from the casting.

Forgings—The test specimen shall be cut cold from the forging or full-sized prolongation of the same parallel to the axis of the forging and half way between the center and outside, the specimens to be longitudinal, *i.e.*, the length

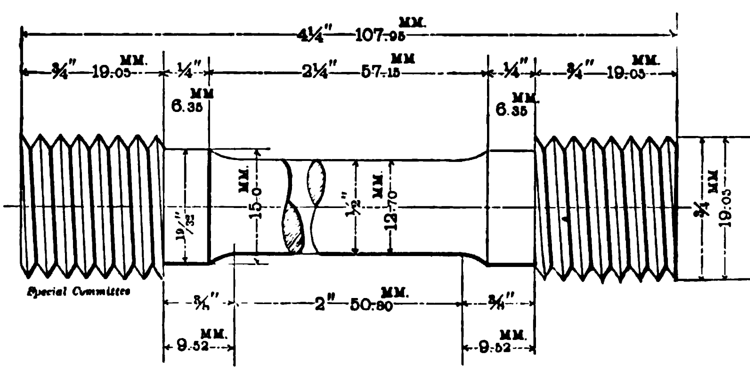


Fig. 146.

of the specimen to correspond with the direction in which the metal is most drawn out or worked. When forgings have large ends or collars, the test specimens shall be taken from a prolongation of the same diameter or section as that of the forging back of the large end or collar. In the case of hollow shafting, either forged or bored, the specimen shall be taken within the finished section prolonged, half way between the inner and outer surface of the wall of the forging.

Bending Tests.

Bending test may be made either by pressure or by blows.

Cold bending tests are to be made on the material in the condition in which it is to be used. For a quenched bending test the specimen shall be heated to a light cherry-red as seen in the dark, and quenched in water, the temperature of which is between 80° and 90° Fahrenheit.

Test Specimen.

Plates—One and one-half inches wide and if ¾-inch or less in thickness with opposite faces rolled. If over ¾-inch thick, specimen may be reduced to ½-inch. Edges are to be milled or planed.

Rivet Rounds—Tested full size as rolled.

Castings and Forgings—Specimen one inch by one-half inch.

Number of Test Specimens.

Plates—One cold bending and one quenched bending specimen from each plate as it is rolled.

Rivet Rounds—Two cold bending and two quenched bending specimens for each melt.

Location of Specimen.

Castings and Forgings—As specified for tension specimen.

Chemical Analysis.

Turnings from tensile specimen, drillings from tensile or bending specimen or drillings from small test ingot may be used for chemical analysis.

For locomotive fire box steel check analysis may be required from the tensile specimen of each plate as rolled.

Drop Test.

A test to destruction may be substituted for the tensile test, in the case of small or unimportant castings, by selecting three castings from a lot. This test shall show the material to be ductile and free from injurious defects, and suitable for the purposes intended. A lot shall consist of all castings from the same melt or blow, annealed in the same furnace charge.

Percussion Test.

Large castings are to be suspended and hammered all over. No cracks, flaws, defects, nor weakness shall appear after such treatment.

Homogeneity Test for Fire Box Steel.

A sample taken from a broken tensile test specimen, shall not show any single seam or cavity more than one-fourth inch ($\frac{1}{4}''$) long in either of the three fractures obtained as described below.

A portion of the broken tensile specimen is either nicked with a chisel or grooved on a machine, transversely about a sixteenth of an inch ($\frac{1}{16}''$) deep, in three places about two inches (2″) apart. The first groove should be made on one side, two inches (2″) from the square end of the specimen; the second, two inches (2″) from it on the opposite side; and the third, two inches (2″) from the last, and on the opposite side from it. The test specimen is then put in a vice, with the first groove about a quarter of an inch ($\frac{1}{4}''$) above the jaws, care being taken to hold it firmly. The projecting end of the test specimen is then broken off by means of a hammer, a number of light blows being used, and the bending being away from the groove. The specimen is broken by the other two grooves in the same way. The object of this treatment is to open and render visible to the eye any seams due to failure to weld up, or to foreign interposed matter, or cavities due to gas bubbles in the ingot. After rupture, one side of each fracture is examined, a pocket lense being used if necessary, and the length of the seams and cavities is determined.

Branding.

Every finished piece of steel plate shall be stamped with the melt number, and each plate, casting or forging and the coupon or test specimen cut from it, shall be stamped with a separate identifying mark or number. Rivet steel may be shipped in bundles securely wired together with the melt number on a metal tag attached.

Variation in Weight.

The variation in cross section or weight of more than 2½ per cent. from that specified will be sufficient cause for rejection, except in the case of sheared plates, which will be covered by the following permissible variations:

Plates 12½ pounds per square foot or heavier, up to 100 inches wide, when ordered to weight, shall not average more than 2½ per cent. variation above or 2½ per cent. below the theoretical weight. When 100 inches wide and over 5 per cent. above or 5 per cent. below the theoretical weight.

Plates under 12½ pounds per square foot, when ordered to weight, shall not average a greater variation than the following:

Up to 75 inches wide, 2½ per cent. above or 2½ per cent. below the theoretical weight. 75 inches wide up to 100 inches wide, 5 per cent. above or 3 per cent. below the theoretical weight. When 100 inches wide and over 10 per cent. above or 3 per cent. below the theoretical weight.

For all plates ordered to gauge, there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table:

TABLE OF ALLOWANCES FOR OVERWEIGHT FOR RECTANGULAR PLATES WHEN ORDERED TO GAUGE.

Plates will be considered up to gauge if measuring not over $\frac{1}{100}$-inch less than the ordered gauge.

The weight of 1 cubic inch of rolled steel is assumed to be 0.2833 pound.

Plates ¼-inch and over in thickness.

Thickness of plate. Inch.	Width of Plate. Up to 75 inches. Per cent.	75 to 100 inches. Per cent.	Over 100 inches. Per cent.
¼	10	14	18
$\frac{5}{16}$	8	12	16
⅜	7	10	13
$\frac{7}{16}$	6	8	10
½	5	7	9
$\frac{9}{16}$	4½	6½	8½
⅝	4	6	8
Over ⅝	3½	5	6½

Plates under ¼ inch in thickness.

Thickness of plate. Inch.	Width of Plate. Up to 50 inches. Per cent.	Width of Plate. 50 inches and above. Per cent.
⅛ up to 5/32	10	15
5/32 " 3/16	8½	12½
3/16 " ¼	7	10

Finish.

All material must have workmanlike finish.

Plates must be free from injurious surface defects and laminations.

Castings must be true to pattern, free from blemish, flaws or shrinkage cracks. Bearing surfaces shall be solid and no porosity shall be allowed in positions where the resistance and value of the castings for the purpose intended will be seriously affected thereby.

Forgings must be free from cracks, flaws, seams or other injurious imperfections, and must conform to dimensions.

Inspection.

The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

Respectfully submitted,

H. W. Spangler, *Chairman.*

Steel.	Chemical Properties.			Physical Properties.			Bending.	
	Phosphorus (not over), per cent.	Sulphur (not over), per cent.	Manganese, per cent.	Tensile strength, lbs. per sq. in. (Allowable variation, ± 5,000 lbs.)	Elongation in 8 inches, per cent.	Contraction of area, per cent.	Around a diameter of—	Through — degrees.
Boiler Plate & Rivet:								
Extra soft...	.04	.04	.30 to .50	60,000	28 †	....	Flat.	180
Fire box...	Acid, .04 / Basic, .03	.04	.30 to .50	55,000	26 †	....	Flat.	180
Flange or boiler	Acid, .06 / Basic, .04	.04	.30 to .60	60,000	25 †	....	Flat.	180
Forgings:								
Soft	.06	.05	....	60,000	22	35	½"	180
Medium	.06	.05	....	70,000	16	30	1½"	180
High........	.04	.04	....	80,000*	18	35	1"	180
Castings. (When physical requirements are not specified carbon must be less than 40 per cent. and phosphorus less than .08 per cent.):								
Soft	.05	.05	....	60,000	16	30	1"	120
Medium	.05	.05	....	70,000	14	25	1"	90
Hard	.05	.05	....	80,000	12	20	....	....

* For carbon steel, to be annealed and having no diameter nor thickness greater than 10 inches, allow a reduction of 1,000 pounds for each additional inch in diameter or in thickness of section.

† For material over ¾ inch thick deduct 1 per cent. for each ⅛ inch excess. For material under 5/16 inch thick deduct 2½ per cent. for each 1/16 inch decrease.

The Committee submits this as a tentative report, and asks for it the careful consideration of the members of the Society who are interested in the subject.

Mr. Henning.—From what Professor Spangler has said I am simply amazed. There are statements made in the report which cannot be supported. The determination of a very important property indicated by the "yield point" has been dropped because it has become the custom in our mills to run machines at such speed as to make it impossible to determine it. Now, I am going to stand and fight for this, the determination of this point, until I am dead. It is time to put a stop to such preposterous audacity. I tell you, gentlemen, as engineers, that we should rather determine the permanence and the actual strength of all machines and structures, not by the ultimate resistance, the breaking point, but solely by the location of the yield point, that point at which the material begins to change its shape permanently. A lathe, a machine, a bridge or boiler, once it begins to change its shape permanently, is ruined. It has become the custom in this country to run testing machines at such speed that no one can tell whether the beam is floating at zero and indicating the load that is transmitted to the test piece, and I am ready to prove that in court or anywhere else. Under such conditions it is absolutely impossible to determine the yield point or any other facts. The elastic limit is something we need not talk about, because it is difficult to determine, except by the most sensitive apparatus. The method here described is absolutely inaccurate. I will tell you why. When you determine the one-thousandth of an inch of elongation it can only be done by applying a load to the test piece and taking a reading by very delicate apparatus; it must read to the ten-thousandth of an inch in order to get accurately the thousandths of inches. When you take a reading and stop the load and then reload that material, it begins to stretch slightly, but the yield point will thereby be raised.

I wish to prevent such a report going into print. What I am stating are well known facts.

Therefore, I do not want such specifications proposed when there are methods for determining the yield point accurately—by simply running the testing machine at a proper speed. I repeat, that by running a machine as rapidly as stated, no one can know whether the beam is kept floating by the loads applied or by inertia, and I object most strongly to such statements appearing at this late date in a report of this society.

No. 980.*

UNITED STATES ARMY GUN FACTORY, WATERVLIET ARSENAL, N. Y.

BY JOHN M. B. SCHEELE, WASHINGTON, D. C.
(Junior Member of the Society.)

1. The object of this paper is to give a general description, and is particularly intended for those members who will have an opportunity to visit the United States army gun factory at Watervliet Arsenal, New York; where the largest and most powerful gun in the world has been built. It is the only Government army gun factory in the country. Work of similar character is also being done at the Washington navy yard for the naval service.

2. Watervliet arsenal was established in 1813 as a military establishment principally for the manufacture of field, siege and sea-coast carriages. Field carriages and leather equipment work continued to be manfactured at the arsenal up to the establishment of the gun factory in 1887, when the harness manufacturing was transferred to Rock Island arsenal, and later on the field carriage manufacturing was also transferred to the same arsenal. The shop, built in 1887, is now used and especially equipped for the manufacture of field and siege guns, which is a distinct and separate department from the sea-coast gun shop.

In the south wing of the field and siege gun shop will be seen an annealing furnace designed and built by the Rockwell Engineering Company, of New York, for the purpose of heating the jackets and hoops before their shrinking on the field guns. This furnace is built in a cemented pit fifteen feet deep below floor level, leaving eighteen feet above the floor; the outside diameter of shell is 12 feet by $\frac{5}{8}$ of an inch thick. It is fired by means of several oil burners using kerosene as fuel, which furnishes the

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

desired range of temperature variable at will from 800 to 1,400 degrees Fahr.*

The demand for sea-coast guns of large calibres necessitated the erection of a shop exclusively for this purpose. A shop 1,000 feet in length was built; the north wing with the central section being 600 feet by 130 feet wide, completed and in productive order in 1890; the south wing 400 feet by 150 feet wide assumed its activity in 1895.

3. The sea-coast gun shop is equipped with about forty gun lathes, classified as gun lathes, jacket and hoop lathes, which are capable of handling guns up to sixteen inches in calibre. Of the lathes four have a capacity to take in assembled 16-inch guns.

All boring, reaming, turning, and facing operations of the tubes, jackets, large hoops and the assembled guns are performed in these lathes; short hoops are usually turned, bored and faced in regular boring and turning mills or in cylinder boring machines. In addition to the above-named tools, special machines are also available for the principal remaining operations on the gun, such as rifling the bore, threading and slotting the breech.

A large number of modern standard machine tools are used for the making of the breech mechanisms which are fitted to each gun. The metal employed in gun construction is low carbon steel, melted by the open hearth process and cast into suitable ingots at the works of the manufacturers. The forgings as received at the army gun factory are tempered, annealed, and rough-machined all over. Approximately twenty per cent. to twenty-five per cent. of metal is removed by the various tools and appliances at the gun shop for producing the finished guns.

4. Of the five overhead travelling cranes in the shop, the largest has a capacity of 130 tons. It is the usual practice to convey material and assembled guns exceeding five tons in weight by these cranes and transport lighter pieces by means of shop trucks and the hoisting facilities in the side aisles.

The central section contains, besides the steam and electric plant, a shrinkage pit excavated in the solid rock. The pit is provided with two furnaces, operated by oil and high pressure steam, for heating the parts or hoops before uniting to form the

* The temperature can either be kept constant throughout the entire height of the furnace or be varied to the extent of 100 degrees Fahr., the higher temperature either being at top or bottom of the furnace.

whole, built up or hooped gun. In the central section is also located the tool room, where the most accurate gauges, jigs and tools used for the various operations are made. An assortment of tools is also kept in this room conveniently arranged with regard to the frequency of their use.

Opposite the tool room, on the other side of the shop, are the smith fires, all smith work being under the direction of the master mechanic, except the tool-dressers, who are under the immediate supervision of the foreman of the tool room.

5. In the central section of the sea-coast gun shop, south of the steam and electric plant, is a department provided with a transfer comparator, designed for laying off the distances defined on a line standard bar, establishing definite distances between or over the ends of contact points for the adjustment of end measures, either for interior gauge rods and measures or for exterior diameter calipers. Its capacity is from zero to seventy inches for gauge rods, and five to seventy-five inches for exterior calipers. (This machine was manufactured at Watertown Arsenal, Massachusetts.)

Outside and in front of this latter department will be seen the so-called star gauge instruments used for the control measuring of the bore in the guns. Its operation is based on the principles of four micrometers, placed radially in a star-shaped body attached to a long tube.

6. The management of the army gun factory is under the direct supervision of a commanding army officer, who is held responsible for the general administration and all work done in the shops.

The master mechanic, who is a civilian, is under the immediate supervision and direction of the commanding officer, responsible for the condition of the power plant, consumption of fuel and oil, lighting and heating, installations, proper use of machine tools and appliances. The designing of machines and tools and determining the best method of using the same are also part of his duties. He is also in charge of all the employees in the gun shops and all construction work on guns of every calibre. The work is allotted by him to the different foremen, who have their separate machines, workmen, and perform their work in designated parts of the shops.

7. The machinists and all skilled mechanics are employed under the system of local civil service board, the civil service

law being carried out strictly within the provisions of the Government requirements, thus applying the merit system to all applicants.

Records are kept of each employee, which are examined from month to month. This method enables the board to investigate the employees' standing and efficiency, also to recommend an increase of wages and promotion to the next higher class for those who have proved themselves worthy.

The promotions are generally made quarterly. The machinists are divided into four classes—namely, the special class, first, second and third; their wages ranging from $2.72 to $3.28 per diem for eight hours work per day, foremen not being included in these classes.

To each employee who has served not less than one year is granted fifteen days annual leave with pay, and all employees are paid for the general holidays.

8. The approximate output of the large gun shop per year is ten 5-inch, thirteen 6-inch, sixteen 10-inch, sixteen 12-inch guns and twenty 12-inch mortar guns or their equivalent; and the capacity of the small shop about one hundred and seventy-five field guns, ten 5-inch siege guns, eleven 7-inch mortars, and ten 7-inch howitzers, thus aggregating a total of two hundred and eighty-one guns per year. The above figures are based on working one shift of eight hours per day.

No. 981.*

TEST OF A HYDRAULIC ELEVATOR SYSTEM.

REGINALD PELHAM BOLTON, NEW YORK CITY.
(Member of the Society.)

1. THE contractors for the installation of 33 hydraulic elevators in the new department store of R. H. Macy & Co. gave a guarantee that the cost of fuel for its operation should not exceed 6 cents per mile of car travel, coupling with this the stipulation that the water should be pumped by 3-throw crank and flywheel compound pumping engines, and that the boiler used should afford an evaporation of 10 pounds of water per pound of coal, and, finally, that the coal to be used should not exceed in cost $4.00 per ton.

In letting contracts for pumps and boilers these conditions were followed, and guarantees exacted from the respective manufacturers. In the case of the pumps, a guarantee of steam consumption not exceeding 25 pounds of steam per indicated horsepower was procured, and the boilers were guaranteed to afford an efficiency of 70 per cent.

2. On March 15, 1903, the writer conducted a test of the combined apparatus, which, being carried out without any of the interferences which have been encountered in other tests of elevators, with a complete elimination of other apparatus, and at a time when the uninterrupted use of the necessary cars was at disposal, is of so complete, as well as satisfactory, a nature as to warrant the attention of the members of the Society.

3. The elevators are large passenger cars of a full carrying capacity of 3,000 pounds, at a speed of 300 feet per minute, operating from the basement floor to the 8th, 9th and 10th floor levels.

They were constructed by the McAdams & Cartwright Eleva-

---

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

tor Co. of New York, and are provided with that company's hand-lever controls, are counterweighted to 650 pounds unbalanced weight, and are provided with slack chains counterweighting the cables, which chains are attached to the car and the counterweight, giving a very accurate average weight of rope.

They are operated by vertical hydraulic cylinders 15 inches diameter, geared 4 to 1, and provided with pilot valves using 2 gallons of water to each complete reversal.

The working pressure is 140 pounds per square inch.

4. Those selected for the test are known as Nos. 1, 2, 3 and 4, being a bank of passenger cars in the southeast portion of the building, having a round-trip travel of 292.5 feet net per car, and Nos. 5 to 10 inclusive, being the passenger bank on the west end of the store, having a round-trip travel of 324.5 feet net per car.

Each car was loaded with a weighed live load of 1,000 pounds inclusive of the operator, which was taken to represent an average load in cars of their proportions, and afforded a rate of down-travel uniform with that of the up-run.

These elevators were selected as being those representing the average distance of cylinders from the pressure drums, so that the frictional hydraulic resistance is representative of average working conditions of the whole plant.

The cars were run on a schedule from bottom to top of travel and at such a number of trips as to reach as nearly as practicable a total travel of 30 miles per hour, which travel utilized the full and reasonably regular capacity of one of the two main pumps, which is the normal condition of the regular service of the building.

5. The pumps are two in number, and are duplicates. They are the high-duty type manufactured by the Laidlaw-Dunn-Gordon Company of Cincinnati, having a horizontal high-pressure cylinder $22\frac{1}{2}$ inches diameter, set between two low-pressure cylinders, each 28 inches diameter, all 24 inches stroke, each operating a crank on the crank-shaft by rocking levers, and connected to three water pumps, each $14\frac{3}{4}$ inches diameter by 24 inches stroke.

During the trial the pumps were interchanged so that the result shows the average of their respective conditions. This was somewhat to their disadvantage, as No. 2 had a defective water-valve.

6. The steam cylinders have Corliss valves, and the high-pressure steam supply is automatically controlled by the rising pressure in the pressure drums. There is a re-heater between the high-pressure exhaust and low-pressure intake, the steam for which is charged in as part of the work, its condensation being run to waste during the trial.

The low-pressure cylinders exhaust into the general exhaust

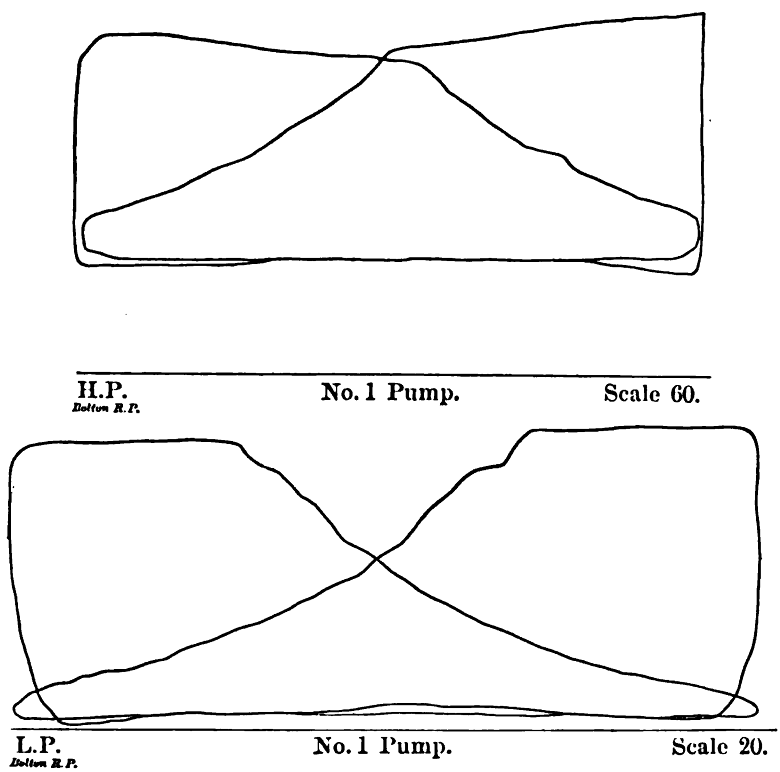


Fig. 147.

system, which, during winter, is taken up entirely in house-heating work, but at the time of the trial was freely exhausted to the atmosphere through the 20-inch exhaust main about 380 feet in length.

Indicator cards were taken at regular intervals of 15 minutes. A sample set of cards from each engine is appended.

7. The boiler was of the water-tube type with forged steel headers, constructed by the Babcock & Wilcox Co. of New York, and is of 293 rated horse-power. In the result it proved

to be in excess of steam requirements, being operated below its rating, at an output of 255 horse-power, or 89 per cent. It has 140 18-foot tubes 4 inches diameter, arranged 14 tubes wide by 10 tubes high, and has 2 drums, each 36 inches diameter by 22 feet $3\frac{5}{8}$ inches long. It is set in a separate setting, and is connected to the end of the smoke breeching of the south battery, which

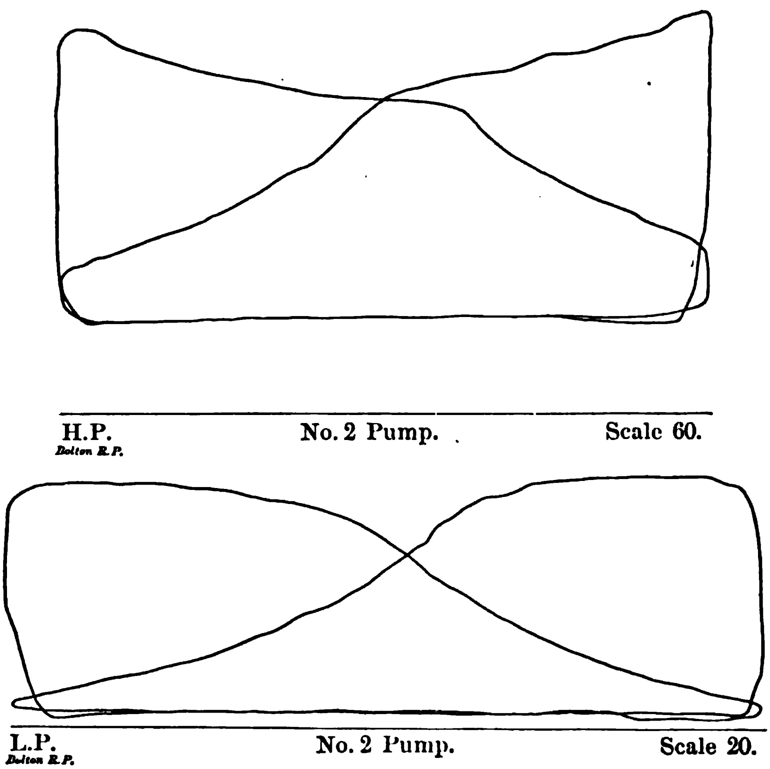


FIG. 148.

is about 220 feet in length and connects to a 10-foot stack 185 feet in height above grate-bars.

8. The furnace system is that of the Parson Manufacturing Company of New York, consisting of a grate of 59.5 square feet area, composed of cast-iron bars $1\frac{1}{2}$ inches thick, with circular coned air openings, the area of which on the fire surface aggregates only about 8 per cent. of its total area. Air is supplied under pressure, in a closed ash-pit, by two special steam jet blowers at the side of the setting. For the purpose of this test the steam supply to these blowers was taken from another boiler,

but the control of the blowers was effected by an automatic regulator, the operation of which was varied by the steam pressure of the boiler under test.

The amount of steam used by the jets was measured by an apparatus suggested by Mr. Hosea Webster, M. E., consisting of a steam supply taken through a perforation of known size inserted in the supply pipe, with a pressure gauge on each side. Readings being taken therefrom, a separate blower-nozzle was connected by a hose, and being placed in a tub of water, the steam condensed by its use for a given time was weighed.

9. The arrangements for the test were laid down beforehand by the writer, and the rather numerous observers assigned to their duties, in a memorandum to which the representatives of all interested parties agreed, and in which the results to be sought were also stated.

A preliminary run was also made on the 11th of March, for two hours, in order to ascertain that all apparatus was in order, and to accustom the observers to their duties.

The general arrangements for the test comprised a separate feed-pump supplying the boiler under test, the pump being supplied with steam from another source, and being supplied with water weighed in the usual manner.

The feed was passed through a superheater or economizer on Kieley & Mueller's system, which consists of a single large pipe extending through the upper part of the smoke breeching. The feed was confined entirely to the boiler under test.

The steam from the boiler was conducted by a separate supply main only to the pump under operation. This main was dripped at its end, and a drip was also led from a Kieley steam separator placed over the stop-valve of each of the pumps. These drips were provided with separate bucket-traps discharging through a cooling coil into a tub on a weighing scale. The pump was charged with all the feed-water pumped to the boiler, less the amount of drips thus weighed back.

Steam was tested for contained moisture at the boiler outlet.

The fuel used was an excellent grade of anthracite of buckwheat size, commonly known as No. 2, and cost, delivered into the bunker, $2.55 per gross ton of 2,240 pounds.

The test, as it related to the boiler, was conducted under the conditions established by this Society, the start and stop being made on the "alternate" method.

10. The observations recorded are shown in accompanying tabulation.

SUMMARY OF READINGS TAKEN DURING TEST OF ELEVATORS, PUMP, BOILER AND FURNACE SYSTEM AT R. H. MACY & CO.'S BUILDING, NEW YORK CITY, MARCH 15, 1903.

Time.	Feet travelled by cars per hour.	Pump revolutions per hour (52.758 gallons per revolution).	Net steam to pump (lbs.).	Water to boiler per hour (lbs.).	Coal consumed (lbs.).	Ash.	Combustible.
9.30	165,982.5	3,630	6,651.5	6,778	......	....	......
10.30	161,490.0	3,570	7,507.5	7,628	......	....	....
11.30	161,586.0	3,218	7,277.0	7,613	......	....	....
12.30	166,357.5	3,655	8,285.0	8,478	......	....	....
1.30	167,139.0	3,645	6,453.5	6,612	4,691	567	4,023.61
2.30	164,991.0	3,590	7,145.5	7,290	......	....	......
3.30	168,108.0	3,715	7,875.0	7,977	......	....	....
4.30	164,602.5	3,518	6,844.0	7,037	......	....	....
5.30	167,437.0	3,630	6,707.5	6,886	......	....	....
6.30	168,400.5	3,653	7,874.0	8,043	4,749	467	4,180.37
Totals....	1,656,084.0	35,824	72,620.5	74,342	9,440	1,034	8,203.98
Averages.	165,608.4	3,582.4	7,262.05	7,434.2	944	103.4	820.39

Average flue temperature	Degrees Fahr.	413.55
" feed-water temperature	" "	75.18
" steam pressure	Pounds	132.2
" pressure in ash-pit	Inches	.60
" draught in furnace	"	.19
" " flue (outside damper)	"	.40
" " " (inside damper)	"	.225
B. T. U. per pound coal		13,138
Moisture in coal	Per cent.	2.14
" " steam	Of one per cent.	.22
Steam used in jets per hour	Pounds	565.8

The net results demonstrated the following facts:

Per car mile, fuel	32.32	lbs.
" " " steam	231.5	"
" " " water pumped	6,025.	gals.
Live load actually lifted, per car mile	2,640,000	foot-lbs.
Live load actually travelled, per car mile	5,280,000	"
Live load lifted per pound of fuel	81,370	"

PUMP.

Steam per indicated horse-power per hour	24.717	lbs.
Steam per water horse-power per hour	29.094	"
Water pumped per pound of fuel	186.39	gals.

Piping.

Losses by condensation, per cent. of steam delivered from the boiler	2.36	

Boiler.

Steam quality, contained moisture, of one per cent	.22	
Direct evaporation per pound of coal, from feed at average of 75.18 degrees Fahr.	8.04	lbs.
Evaporation from and at 212 degrees Fahr., per pound dry coal	9.56	"
Evaporation from and at 212 degrees Fahr., per pound of combustible material	10.77	"

Grate System.

Fuel burned per square foot per hour	15.86	lbs.
Steam used to operate blowers per hour	565.8	"
Equivalent coal at evaporation of 8.04	70.	"

Coal.

Thermal value. Heat units	13,138
Moisture, per cent. of total weight	2.14
Ash and clinker, per cent. of total weight	10.95

From the above are worked out the following results of efficiency of each part of the apparatus in terms of the heat units contained in the fuel.

Efficiencies.

Coal, per cent. of perfect combustibility	86.91
Furnace, per cent. of heat received and liberated under the boiler	92.59
Boiler, per cent. of heat liberated, absorbed and delivered as steam, or efficiency	70.27
Piping, per cent. of heat received from the boiler and delivered to the cylinder	97.69
Pump cylinder, per cent. of heat received and turned into mechanical work	8.647
Pumping engine, per cent. of heat in piston work turned into water pumped	84.95
Elevator system, per cent. of work received in water pumped, represented by	
1. The average live load raised	15.61
2. The maximum live load raised	46.83

11. As the operation of the system involves the lifting of a greater weight than the load lifted in order to return the said load to the ground, which process is a part of the desired results,

it is proper to state the effective results of the system in terms of the above loads travelled, when the respective efficiencies of the elevator system as stated above are doubled;

or (1) The average live load travelled	31.22
(2) The maximum live load travelled	93.66

EFFICIENCY OF THE COMBINED SYSTEM OF APPARATUS, FURNACE TO LOAD

Per cent. of heat in the fuel represented by the average live load travelled....................................	1.6
The same by the maximum load travelled	4.8

DISCUSSION.

Mr. George Hill.—This paper records an elevator test intended primarily to determine whether or not the elevators complied with a certain guarantee.

The author was given an opportunity to ascertain something which would have been of great value to himself and to other engineers, which opportunity was not availed of.

I refer to the opportunity to ascertain definitely the difference in operating economy between elevators run under test conditions and those run under normal condition of service. That such a difference exists is a perfectly logical conclusion, from the known difference which exists in almost every other form of plant.

In this case the author states that the valves use a certain amount of water on reversal, which does not represent useful work performed. The amount of waste from this cause was reduced apparently to a minimum.

All of the conditions of the test were arranged to give the highest possible efficiency, and it would be of value to know how the efficiency fell off under working conditions.

As it stands the client will suppose that his elevators are costing him a certain amount, which he can determine by measuring the car miles and multiplying it by 6 and a fraction cents, which is unquestionably a grave error.

The author determined a number of values which give the paper a serious appearance, but which unfortunately have no bearing whatever on the avowed purpose of the test, and are of no practical value in determining what might be called the commercial efficiency of the plant.

While he apparently gives a great deal of data in regard to the plant, the most important information is omitted—that is, the size of the pressure and discharge tanks which absolutely determine the ability of the pumps to work at a uniform speed under ordinary working conditions.

I should criticise his failure to charge the steam used in the jets to the steam consumption of the plant, as it seems to me it ought to be charged against the efficiency of the boiler.

I would also criticise the failure to specifically state the conclusions reached by him from the test. Apparently the boilers failed to comply with the conditions of the guarantee, the pumps did comply with the conditions, and the elevators did not.

Mr. R. L. Gifford.—The fuel cost of operation of hydraulic elevators is usually the most difficult item to separate from the total operative cost of large building plants, as the regularity of the service must be maintained, and usually the elevator pump steam supply is taken from a common header supplying other engines and pumps.

The conditions of these tests were favorable for accurate results, and the paper is of corresponding value. The load and running conditions of the test as well as the high efficiencies of all parts of the installation, were favorable to the best obtainable economy for hydraulic elevators, and for the department store service where the elevators carry full loads all day the results obtained will closely approach actual running conditions. In actual running, however, the reversals due to running past floor landings at stops, and the consequent demand for pilot valve water, would increase the water consumption 3 per cent. or 4 per cent.

For office building service the assumption of a constant live load will give a greater efficiency in live load raised than actual random loads, for the load is extremely variable, and an up trip with one passenger will call for the same consumption of power as a loaded car, furthermore, the variable load prevents as accurate counter weighting as was possible in this test.

For variable loads the electric elevator has the advantage in that consumption of current is a direct ratio to load raised.

The fuel cost per car mile including steam for jets is only $3\frac{7}{10}$ cents, which is about the best economy obtainable with electric elevators of similar lifting capacity and speed on random loads. A test recently made on an electric installation of similar capacity showed a consumption for motor and controller of 3.8 kilowatt hours per car mile, actual running conditions, or a fuel cost of about 3½ cents per car mile with current costing 1½ cents per kilowatt hour at the switchboard (fuel cost being 60 per cent. of same).

In small plants where the load is hooked on to a central station and the current costs 4 cents or 5 cents per kilowatt hour, the cost of operation of an electric elevator is from 15 to 20 cents per car mile.

Steam elevators of equal capacity and speed as the hydraulics tested, use about 1,000 pounds of steam per car mile. An actual test under similar conditions to the one under discussion gave 977 pounds of steam per car mile, which, at the same cost of evaporation as in the Macy plant (steam used by jets included), would give a fuel cost of about 12¼ cents per car mile.

Only a small per cent. of hydraulic elevator plants are equipped with the high duty type of pumps used here, the compound duplex pump usually installed using upwards of 80 pounds of steam per horse power hour, with a corresponding fuel cost of four times as much as in the Macy plant.

The temperature of feed water, 75.18 degrees Fahr., indicates that no feed water heater was used, and while the omission does not affect the boiler efficiency results obtained, the fuel economy of the plant would of course be improved by the use of a heater. In fact a heater would be many times as effective as the economizer used, and from the low flue temperature noted it is safe to conclude that the economizer reduced the draft, which was naturally so poor that steam jets were installed to boost it.

On page 939 in table of boiler results, the steam used by the jets is charged against the furnace. For comparison of cost of evaporation with other boiler plants, these results would be reduced by including the coal equivalent of the steam supplied to the jets from another boiler in addition to coal burned direct on the grates. Taking this into account, the results show an evaporation from and at 212 degrees Fahr. of 9.02 pounds per pound dry coal, and a coal efficiency of 65 per cent. for boiler and grate combined.

Mr. John B. Blood.—I might bring forward a point that, in the case of Mr. Bolton's maximum load travel, he has multiplied the efficiency by 3 in each case, whereas if the maximum load was in the elevator and went up and down every time, the amount of steam supplied to pump would be increased. He has apparently calculated the efficiency assuming that the steam in the pump would be the same if the load in the elevator was increased to the maximum all the time. As a matter of fact, I should think that while the efficiency would not be three times, yet it probably would largely increase. But it stands to reason almost that the amount of energy in the pump would be increased by a maximum load being run in the elevator all the time as against the average load.

*Mr. Bolton.**—Answering the remarks of the last speaker, I would say that in the hydraulic elevator system the carrying of the maximum load in the car does not involve any increase in the pressure, and that therefore it is perfectly correct to multiply the efficiency by 3. Furthermore, the point may be brought out here that in testing or running a heavier load the same work is done within a given time. For instance, in this case these cars were loaded with 1,000 pounds, including the operator. That was done in order that the up speed might be the same as that of the travel of the car back again. If the cars had been loaded with 2,000 pounds they would have gone up slower, but would have descended quicker, so that the total car-travel would have been the same. In that respect the method of loading for the test is correct.

In regard to Mr. Hill's communication, if he had been in charge of the test it would have been only natural, with so many interests around him, for him to have desired to see every part of the apparatus doing its best at once—the pumps, the boilers, and everything working up to their guarantee.

The total cost per car mile was $3\frac{67}{100}$ cents.

The test was made on a Sunday morning when the store was closed, because on a week day a totally different set of conditions would have been present.

The pressure tanks are two in number, 7 feet diameter by 25 feet long, and are very ample for the work. For some years I have been insisting on larger pressure tanks than used to be the practice.

The boiler contract was separate from that of the grate system, consequently the steam used by the jets could not in this case be charged against the efficiency of the boiler alone. The efficiency of the boiler is in any case better stated in this

* Author's Closure, under the Rules.

way, and as it utilized 70.27 per cent. of the heat afforded to it by the grate system, it fully complied with the guarantee. The efficiency of the grate and boiler combined was in this case a different matter.

Replying to the communication of Mr. Robert L. Gifford, the electric elevator does appear on the face of things, to possess an "advantage in that consumption of current is a direct ratio to the load raised." But what such advocates of electric operation cannot seem to grasp is that this is discounted by the disproportionate cost of the electric equivalent of the pressure drum—viz.: the storage battery, and that when an hydraulic car is ascending with a light load, it does so at a greater speed, and therefore in schedule service the difference in favor of the electric system not only disappears but becomes a large balance on the other side.

The test quoted by Mr. Gifford is on the usual lines of an assumption of fuel used for a kilowatt hour. It would be an advantage if a test could be conducted of a positive nature with a weighed load such as that which I have recorded. I conducted a test on electric elevators some years ago and found that the fuel cost with a light random load exceeded 4 cents per mile.

There is, of course, a feed heater in the plant, but being of the open type, it was necessarily cut out of the test. Its absence does not affect the results recorded. The normal feed temperature is from 180 degrees upward. The flue temperature at the boiler tested could not have been reduced by the economizer, and the natural draft was that due to the use at the time of only three boilers out of the battery. The point which seems to have escaped the writers of both criticisms is that the blower system enabled a cheaper grade of fuel to be used than with natural draft.

I am confirmed in the statement, by the opinion of the leading elevator engineers, that the test recorded is the only clean and positive record on elevator work, and forms a basis on which direct comparisons can be made with future tests.

No. 982.*

A RATIONAL TRAIN RESISTANCE FORMULA.†

BY JOHN BALCH BLOOD, BOSTON, MASS.
(Associate Member of the Society.)

1. In the early days of train resistance formulæ, when speeds were not high, the frictional resistance of track and journals was a considerable factor in the total resistance. Again, the head resistance was charged up to the locomotive, without a formula, and train resistance meant the pull on the engine drawbar.

These facts, together with the fact that the criteria of industrial competition were loosely drawn, made a simple formula the desideratum, and we see as a result formulæ of many varieties containing a single variable.

These served their purpose at the time, but time and advancing knowledge showed their inadquacy both as to absolute results and functionally. The immediate needs were supplied by sets of formulæ with different coefficients and variables, each good only for a certain range.

The original single variable formulæ were of two kinds, as follows:

$$R = A + BM \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$
$$R = A + CM^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Where R = train resistance in lbs. per ton,
M = speed of train,
A, B, and C = coefficients.

2. The development from these formulæ showed a desire for a rational formula, the elements of which would represent dis-

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

† For further references on this subject see *Transactions* as follows:
No. 924, vol. xxiii., p. 269: "Cost of Running Trains at High Speed." F. R. Hutton.

tinct parts of the resistance recognizable and measurable. Experiments and the gradually increasing train speeds began to indicate the different elements of resistance, although the function and absolute value of each was not obtained.

The higher normal train speeds brought out the fact that a factor of the resistance was the air friction, and that it certainly varied as a function of the speed greater than unity, and in all probability as the square.

3. In 1885, the Eastern Railway of France made some very extensive experiments, and gave as their results a set of formulæ of a rational type, using different coefficients for different ranges of speed. Their formula was of the type

$$P = (A + BM)\,T + CQM^2 \quad . \quad . \quad . \quad . \quad (3)$$

Where P = total pull or horizontal effort,
M = speed,
T = weight of train,
Q = cross section of train,
A, B, and C = coefficients.

This reduces for comparison with other formulæ to

$$R = A + BM + \frac{CQM^2}{T} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

It will be noted that for trains with a speed of 12–32 kilometres per hour, these engineers left off the last term having the speed factor as the square, leaving a formula of the form (1).

This formula (4) is interesting from a rational standpoint. First, it has two terms with variables; one as the first power of the velocity, and one as the second power of the velocity. Second, the second power factor has a component, the cross-section of the train. This would show that this factor was to give the air resistance, and would show that they appreciated that there was another part of the resistance that was not constant, and yet it did not vary as the square.

4. Their set of formulæ, instead of a single formula, showed that their variables were not functionally correct, and must be modified by variation of the coefficients.

The set of formulæ as given by them is as follows:

(a) For freight trains speeds 12–32 km. per hour.
$W = (1.65 + 0.05\,v)\,Q.$

(b) For passenger trains speeds 32–50 km. per hour.

$$W = (1.8 + 0.08\, v)\, Q + .009\, Av^2.$$

(c) For passenger trains speeds 50–65 km. per hour.

$$W = (1.8 + 0.08\, v)\, Q + .006\, Av^2.$$

(d) For express trains speeds 70–80 km. per hour.

$$W = (1.8 + 0.14\, v)\, Q + .004\, Av^2.$$

Where W = resistance of train in kilograms,

Q = weight of train in tonnes of 1000 kg.,
V = speed in km. per hour,
A = cross section of trains (5 qm.).

These formulæ were very accurately constructed from careful and exhaustive experiments, and the variation in the coefficients will serve to indicate the functional inadequacy of the variables.

There are four points to be observed in the variation of these coefficients. First, that the factor independent of the speed was apparently constant at all speeds. The deviation from this in case of freight trains could probably be accounted for by the construction of the car or the relative weight of load per axle. Second, it will be seen that the coefficient of the first power factor is increased as the speed increases. Third, that the coefficient of the second power term is decreased with increased velocity. And fourth, that the second power term is eliminated from the low-speed formula.

5. From these observations we would draw the following conclusions: that there is a portion of the train resistance that is independent of the velocity; that the air friction factor has little or no influence below 32 kilometres. These seem to be clear.

The increasing of the coefficient of the first power term and the decreasing of the coefficient of the second power term indicate an empirical attempt to adjust the coefficient to take care of improper functional value of the variables.

We find a single variable formula with first power factor gives too small results for high speeds if it is correct for low speeds. We find, also, that a single variable formula with a second power factor gives too high results at high speeds if it is correct at low speeds. This would seem reasonable, as it is apparent that there are at least three forms of friction—plain sliding friction, which is independent of the speed; rolling friction, which varies directly as the speed; and fluid friction, which, in case of air, would vary theoretically as the second power of the speed.

6. It seems, then, perfectly reasonable that a rational formula should have these three terms. Experience shows that while a formula having three terms of zero, first and second power variables, respectively, will give accurate results for a wider range than either of the single variable formulæ, it in common with the second power single variable formula gives too large results at high speeds, if it is correct at the lower speeds.

This is apparently what the engineers of the Eastern Railway of France found, and they tried to counteract this by reducing the effect of the second power at higher speeds by reducing the coefficient, and by increasing the effect of the first power term at higher speeds by increasing its coefficient. It would seem that the increase of the relative moment of the first power term at high speeds was palliative only, rather than that the rolling friction did increase in greater ratio than the first power.

The conclusion to draw from the above is, that the third term of the equation should have an exponent greater than one and less than two.

7. In March, 1899, I presented in the *Street Railway Journal* a rational formula with a third term having an exponent of 1.8, giving reasons somewhat as above to substantiate its reliability. The formula expressed in the same terms as above was:

$$R = 4 + .15\,M + .3\,\frac{M^{1.8}}{T} \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Mr. W. J. Davis gives a formula which gives very accurate results below 40 or 50 miles, but it is generally acknowledged that it gives too high results at higher speeds. The formula is:

$$R = 6 + .13\,M + .35\,\frac{M^2}{T}\,[1 + .1\,(N-1)] \quad . \quad . \quad (6)$$

Mr. Davis gives different coefficients for different sizes of cars, but does not vary them for the speed. The large cars would naturally be used at the higher speeds, so that the coefficients, if adjusted to the higher part of the curve for the larger cars, would give a series of curves with better total results, but would not be any more functionally correct than the French formulæ.

8. There is a point in rational formulæ which is very impor-

tant; namely, that the terms for head and stern resistance have in the denominator a factor proportional to the length or weight of the train. This appears in many formulæ, and is reasonable when it is considered that the head and stern resistance would be independent of the length of the train, and therefore, when expressed in pounds per ton, would be inversely proportional to the weight or length. In most formulæ the weight is used rather than the length.

This would give as a principle that the head and stern resistance, which varies as a power of the speed between one and two, should have a weight factor in the denominator.

It has been found by experiment that the air resistance on the sides of the cars varies as power of the speed higher than the first. It is evident that this factor of total resistance should be proportional to the length or weight of the train, and therefore in our form of formula would have no weight factor in the denominator.

The head and stern resistance can be divided if it is desired. It is found in actual practice that the head resistance is much larger than the stern resistance. Professor Goss's experiments on models show that this head resistance is 6.5 times the stern resistance, and that the head and stern resistance together are about 6.2 times the side resistance of one car.

From collateral evidence it would seem that the coefficient of the variable in the side resistance term should be considerably lower than that of the head resistance term. The air, in case of the side resistance, is not compressed, but is sheared off, and the fluid particles are dragged aside rather than piled up on each other.

On the basis of the above, the rational formula would be:

$$R = A + BM + CM^n + D\frac{M^p}{T} + E\frac{M^p}{T} \quad . \quad . \quad . \quad (7)$$

Where R = resistance in lbs. per ton,
M = speed in miles per hour,
T = weight of train in tons,
n = exponent of side friction term,
p = exponent of head and stern friction terms,
A = coefficient for sliding friction,
B = coefficient for rolling friction,
C = coefficient for side air resistance,

D = coefficient for head air resistance,
E = coefficient for stern air resistance.

Now, we have not yet enough data for determining the proper exponents, nor to separate the exponents into the two forms. Again, as there are always two ends to a string, the head and stern resistance will always come together.

Until we find sufficient evidence to give us the two exponential factors, we will be better served to combine all three exponential factors into one. Again, for general work this would be simpler and sufficiently accurate. We would then have:

$$R = A + BM + \left(C + \frac{D}{T}\right) M^n \quad . \quad . \quad . \quad . \quad (8)$$

9. This is essentially the formula given by me in 1899, the only difference being in the coefficient of the exponential term separating out a factor representing the side resistance which is proportional to the train weight.

Where R = resistance in lbs. per ton,
M = speed in miles per hour,
T = weight of train in tons,
n = exponent = 1.8,
A = coefficient of sliding friction,
B = coefficient of rolling friction,
C = coefficient of side resistance,
D = coefficient of head and stern resistances.

The values of these various coefficients are as follows:

$A = 3$ for heavy freight trains.
$A = 4$ average passenger trains.
$A = 5$ heavy large electric cars.
$A = 6$ medium electric cars.
$A = 7$ light electric cars.

$B = .15$ for light track construction.
$B = .12$ for heavy track construction.

$C = .0016$ for ordinarily constructed cars.
$C = .0014$ for cars with vestibules.

$D = .25$ for small cross section cars.
$D = .30$ for medium section electric cars.
$D = .35$ for large electric or suburban trains.
$D = .40$ for largest express trains.

As our experimental data are increased, it will be possible to correlate these coefficients more intimately with the elements of friction they represent.

The foregoing has shown the gradual development of the train resistance formula from a rational standpoint. It, however, has been viewed all along from the start from an empirical standpoint.

10. When it was found that a formula with a single variable term was insufficient, there were those who refused to add another term to the formula, contending that such term did not give an absolute formula, and only extended its range if results were at all in advance. Again, the range of increased alleged accuracy was within the range of variation in the value of the coefficients, so that altogether the extra complication was not worth the result. These advocated an empirical formula taking such range for each separate set of coefficients as experience would warrant.

There were others, I believe, who were led to abandon the rational formula on account of intellectual cowardice. They found that a single variable formula was hopelessly inadequate with either the first power or the second power. After having passed to the three term formula with first and second power variables, they saw that with the increase of speed and shortening of trains, too high results would be obtained at high speeds. They balked at following the natural and logical course of reducing the exponent of the second power term, arguing, perhaps, that the complication of the fractional exponent was not warranted; also, perhaps, being led by the fact that the theoretical air resistance is known to vary as the second power.

11. Let us consider the uses of a train resistance formula. Originally, it served more as a guide than an engineering hypothesis. As skill in design and application increased, more and more attention was paid to the fitting of machines to the work they had to do. Moreover, with steam railroads and long trains, extreme accuracy was not essential, as one or more cars could be added or taken off as conditions required.

With the advent of short suburban trains with three to five cars, short distances between stations and a demand for increased schedule speed, it became very necessary to fit the motive power with a nicety to its work. In case of a three-car train, if the locomotive was too small, the taking off of a single car would reduce the train weight 33 per cent., and then the locomotive would be too large, besides necessitating a change in the time tables.

This need was still further emphasized by the high speeds of such trains as the Empire State Express of the New York Central and Hudson River Railroad, and also by the high speed interurban electric cars. In case of these electric cars, the motive power of each car being on its own axles, there is no possibility of adjustment if it is not suited to its work.

It will be seen, then, that the use of train resistance formulæ has changed from that of a general guide to that of a fundamental engineering criterion. Extreme accuracy is now a desideratum, functional as well as absolute.

Again, the complication of the number of terms and the fractional exponent is not the drawback that it would appear, as the use of such formulæ now takes the intermediary of charts or curves, eliminating all complication of calculation. Moreover, the general use of the slide-rule makes a fractional power practically as easy of calculation as the integral factor.

Those who argued for the empirical formula pretty generally stuck to the single variable formula, and varied the coefficients to suit the case. There were those who, finding the two variable formulæ inadequate, apparently went on an empirical excursion to find some form which would give accurate results for a wider range than given by existing formulæ. The formula of Mr. John Lundie is of this class, and as stated by him is:

$$R = 4 + S\left(.2 + \frac{14}{35 + T}\right),$$

which, reduced for comparison with rational formula, becomes

$$R = 4 + .20\ M + \frac{14 M}{35 + T} \quad . \quad . \quad . \quad . \quad (9)$$

The third term of this equation cannot be explained rationally. The depreciated reciprocal weight factor has no rational analogy in practice. This formula has all the complications of a three-term formula, without the advantage of rational formula.

12. Mr. J. A. F. Aspinall, the General Manager of the Lancashire and Yorkshire Railway, has gone into the matter of train resistance in an exhaustive manner, and presented in November, 1901, at a meeting of the British Institution of Civil Engineers a paper on the subject. He gave as results of his study and experiments for a five-car train :

$$R = 2.5 + \frac{V^{\frac{5}{3}}}{57.8} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

Where $R =$ resistance in lbs. per ton of 2240 lbs. drawn,
$V =$ velocity of train in miles per hour.

He found that for a greater number of cars that the length entered as a factor and gave

$$R = 2.5 + \frac{V^{\frac{5}{3}}}{50.8 + .0278\,L} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

Where $L =$ length of train in feet.

It will be noticed that the independent coefficient is small. It can generally be taken as a fact that when the independent factor is less than three the formula is empirical, and that the independent coefficient is reduced to compensate some other error introduced. In all formulæ this independent factor represents the resistance just before coming to rest, and is the minimum obtainable resistance. This is seldom less than four pounds, and only in exceptional cases goes below 3.5 pounds.

Mr. Aspinall has the courage to go to a fractional exponent. He, however, combines all variables into one term, thereby cutting loose from a rational formula. He has also a depreciated reciprocal length factor, which is comparable with Mr. Lundie's depreciated reciprocal weight factor. Mr. Lundie has a third term with the first power variable alone, which Mr. Aspinall does not.

Although I am a believer in a rational formula, I was pleased to see Mr. Aspinall's formula, as he is the first man to give, other than myself, a fractional exponent of the variable.

Mr. C. O. Mailloux although he favors a rational formula has found useful an empirical formula of the form

$$R = A + BM^{n} \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

Now, mathematically, this equation can be made to very closely represent any curve with a constantly increasing function, and, therefore, can be made to represent any given test curve, probably, within the limits of accuracy. If a curve be plotted representing a given set of readings, and a curve of form of equation (12) be plotted to represent such curve, if the highest points of the two curves coincide, it will be found that the empirical curve cuts the real curve at two points, and that the values of the resistance as calculated from the empirical curve beyond the upper limit are higher than the true values. It is very important in extending curves to have all points determined as accurately as possible, for a slight variation in direction is magnified by the amount of extension. That this empirical curve would give high results on the extension is obvious when it is considered that a factor varying as the first power of the velocity is eliminated, and its place taken by an augmented coefficient of the higher power factor. At low values of the speed, the difference between the true value of the first power variable and its substituted higher power factor would probably be within the limits of accuracy of observation, but this is not so at high values, and would always lead to high results. This empirical train resistance formula is good to represent a given series of results for mathematical or functional comparison. It, however, is of little, or perhaps better stated, inferior value for predicted results of extension beyond the highest value of observation. It is very important for extending the curve that the first power factor be present and accurately determined as to its coefficient.

13. Another important point which the empirical formulæ entirely leave out is the relative value of the different portions of the resistance. In a rational formula it will be seen that the side air resistance comes within the limits of accuracy at about 30 miles per hour, and the head and stern resistances become negligible for a six-car train at about the same speed; but for a single-car train, they do not become negligible till you get down towards 20 miles per hour. It would seem this is a very important function of a train resistance formula.

14. It would seem, inconclusion, that all arguments favor the rational form rather than the empirical form, and that the highest exponential variable should have a fractional exponent between one and two.

DISCUSSION.

Prof. G. Lanza.—In order to discuss intelligently Mr. Blood's contribution to the voluminous literature extant on train resistance, we must bear in mind that, in order to serve any useful purpose, the results obtained by the use of such formulæ should furnish the resistance with such degree of accuracy as is needed for use in practice. Hence I am deeply interested in any set of formulæ, whether rational or empirical, which will enable us to compute the resistance to be overcome in pulling trains in actual service, with an error not greater than 10 or 15 per cent., and which can be and have been verified by experiments upon trains in actual service.

On the other hand, I am not much interested in formulæ, whether rational or empirical, which will not bear this test.

It is because a great deal has been done by way of devising formulæ of this latter class, and very little has been done by way of making reliable tests, that it seems to me that we have not yet obtained enough reliable data to warrant us in the hope of deducing rational formulæ that shall be applicable to the conditions of service.

To explain more fully the bearing of the above, I will say that the experiments upon which train resistance (whether rational or empirical) have been based have been of the following kinds:

(*a*) Bringing the train up to some point on the road with a known velocity, then letting it run without steam and noting the distance it runs before coming to rest.

(*b*) Observing the initial, and also the final velocity at different points in its travel when running without steam.

(*c*) Starting it at a zero velocity, at the top of an inclined plane, thus letting gravity impart velocity to it, and then letting it run on a level till it stops.

(*d*) By taking indicator cards when it is a question of the entire train, including the locomotive and tender, and by dynamometer, when only the resistance of the cars is desired.

(*e*) In many cases experiments have been made by some of these methods, using only a single car, instead of a train of cars.

It is believed that the only experiments on train resistance from which reliable results for use in practice can be obtained, are those where a recording dynamometer is used when it is a question of the resistance of the cars alone, or where indicator cards are used, when it is a question of the resistance of the entire train including the locomotive and tender.

When any of the other methods stated above are used, the train is not in the condition in which it is when being hauled by the locomotive, as, for instance, if a line of cars be allowed to descend a grade, acted on by gravity alone, the tensions on the train hooks are quite different from those actually occurring in the usual running of a train on a level track; besides which the velocity is a varying one.

When a recording dynamometer is used, a dynamometer diagram is recorded on the roll of paper by one pencil, while another draws a straight zero line, the distance between these lines representing to scale the pull on the draw-bar, while a chronograph makes marks dividing up the straight (zero) line into portions described in equal times, as say, five seconds.

Having had occasion to have the resistance of certain trains deduced from dynamometer diagrams, certain facts developed which it may be well to mention here:

1. In working up such data it is necessary, of course, to take account of the difference of actual energy, and also of the difference of level at the beginning and end of the section under consideration.

2. If the attempt is made to use five-second periods, so much difficulty will be found in a correct determination of the speed that the increase in velocity head due to the consequent inaccuracy is liable to be larger than the head due to dynamometer work, and hence follow very variable and often absurd results.

3. Indeed, two adjacent five-second spaces will often vary by 6 or 7 per cent., and such a variation in the space of five seconds would, in the case of a heavy train running at high speed, require more power than any locomotive could exert while pulling its train.

4. Hence it follows that the use of five-second periods in working up dynamometer diagrams is entirely unsuitable.

5. In view of all the above, the following was the method adopted. Compute the resistance over stretches of straight track at least five miles long, over which the maximum variation of speed does not exceed five miles per hour.

6. It is, of course, of the greatest importance that the dynamometer should weigh the pull correctly, and that no doubt whatever should exist in this regard.

In the light of the above it will be evident, it seems to me, that very few of the train resistance formulæ that have been proposed are based upon such experimental data as will entitle them to the confidence of railroad men, and of the locomotive builders, and moreover, that those quoted by Mr. Blood as having been derived from experiments made upon the Eastern Railroad of France, cannot be included in the list, inasmuch as, according to George Meyer, in "Locomotivbau," of Heusinger von Waldegg, pages 60 and 70, their experiments were made by the following methods:

(*a*) By using single cars, imparting to them a certain initial velocity, and then noting their velocity at fixed intervals, and the distance run before coming to rest.

(*b*) By using single cars drawn by a locomotive with a dynamometer car interposed.

(*c*) By imparting to the locomotive a given speed, and then letting it run with a closed throttle.

(*d*) By pulling a locomotive with its tender, in running order, with closed throttle, the link at the middle, and cylinder cocks open, by means of another locomotive, with a dynamometer car interposed.

(*e*) By hauling a train of loaded coal cars by a locomotive, with a dynamometer car interposed, the speeds being from $1\frac{1}{2}$ to 11 meters per second, the latter being about 24 miles per hour.

Inasmuch as Mr. Blood does not, in this paper, give any account of the experiments upon which he bases his own formulæ, it is not possible to express any opinion regarding their applicability in practice.

It should be observed, however, that, while it is common to give formulæ for train resistance in pounds per ton, it is nevertheless manifestly incorrect to do so, inasmuch as the greater part of the resistances are not proportional to the weights of the trains. Thus the resistance of a train of empty freight cars does not bear to the resistance of the same train loaded, the ratio of their weights.

To discuss the merits of those formulæ which are based upon experimental data of the right kind would prolong this discussion to too great an extent.

Mr. H. Wade Hibbard.—I note a remark in the paper to the effect that "extreme accuracy is now a desideratum, functional as well as absolute." It would be my opinion that the formula, more rational than the old ones although it may be, is still far from being an accurate formula, and I very much doubt whether we can have an accurate formula which will provide for all varying conditions, the vast number of which are entirely unknown. It is a very well known fact that yard-masters, in making up trains for a locomotive of a given draw-bar pull, are obliged to take into consideration whether the train is to be made up of loaded or empty cars, or a mixture. There are many other considerations that affect the draw-bar pull of a train; for instance, whether the trucks are vertically stiff and whether they are horizontally square; whether some of the trucks are side-bearing trucks or centre-bearing trucks; whether the cars are old or new; the material of the axle brasses; the kind of oil, the method of lubrication and condition of the oil. In fact, I have here noted offhand some fifteen different items, none of which the formula seems to have taken into consideration. Probably an attempt to make it do so would render it entirely impractical and unwieldy for general railroad service.

I do not speak in order to throw distrust upon the formula, but simply to point out the burden of my remarks, which is this: that I believe this formula, as many other formulæ—for instance, for columns—should not be considered as absolute formulæ, but should be used for *comparative* purposes. For example, if I am going to design a light side-rod for a high-speed locomotive I would not feel that I could take any formula, as, for instance, the centrifugal force on the rapidly vibrating beam, and take a given fibre stress and feel that that rod was safe. I should want to take a rod from several different engines very similar to the engine which I was going to design, and use the formulæ in analyzing those existing rods, particularly if I am able to find some rods which have broken and some which have not quite broken, and then, having analyzed those rods, use the comparative fibre stress thus found for designing my new rod. In the same way this train-resistance formula, although perhaps better than the old formulæ, is yet a formula which should be used only in some such way as the above—for comparison purposes, and not as an absolutely accurate formula.

*Mr. Blood.**—I would say in reply that I think all formulæ could to a large extent have that same criticism applied to them.

---

* Author's Closure, under the Rules.

The points brought out by this formula are rather its functional accuracy as compared with the functional inadequacy of previous formulæ than to claim for it an absolute value in every case. In the next to last paragraph of section 9, I have meant to emphasize this feature when I said:

"As our experimental data are increased it will be possible to correlate these coefficients more intimately with the elements of friction they represent."

The points which have come up in Mr. Dudley's experiments with rails on the New York Central Railroad would all be taken care of in these various coefficients. Coefficient B is dependent largely upon the tracks. Coefficient A is dependent largely on the pressures, the style of the journals and trucks and the mounting of the cars. By taking the proper coefficients in a rational type formula, a formula would be made up which would give accurate results, and as absolutely as if the resistance were chosen with direct reference to the experimental data on the subject besides being functionally accurate.

The communication of Professor Lanza does not appreciate the points brought out in the above paper, as most of the points he makes would be answered by statements in the paper. Professor Lanza's work in emphasizing the value of full sized actual tests for engineering data is appreciated by the engineering profession. At the same time, this is not the whole of the engineering work, and functional accuracy is as important as absolute results in certain cases. The paper discusses this matter of functional accuracy, and presents a formula for such functional accuracy of the different variables. It is presented in the paper, in next to the last paragraph of section 9, that the increase in the experimental data will bring the formula into more intimate relation with actual results.

Professor Lanza apparently does not appreciate that many of the most important cases where train resistance formula is used, or I might say, many places where an accurate formula is most needful, are those where the conditions are beyond or outside of any heretofore experienced, and which cannot previously have been verified by experiment. In such cases it is exceedingly important that the functional accuracy of the formula be as great as possible, and these cases above all others emphasize the need of a rational formula as against an empirical. If train resistance of an exact relation to some previous experiment is desired, it is useless to have a formula at all, as the records of the experiment will be more accurate than by transforming such records into a formula and calculating back for result. The list of various methods of calculating resistance shows that Professor Lanza is not cognizant of the latest work on this matter. The results taken from electrically propelled trains and cars give opportunity for much greater accuracy on account of the extreme accuracy possible with electrical measurements, and also on account of the uniformity of conditions in the transmission of the electric energy into the mechanical energy of the moving train. The experiments at Zossen, Mr. Davis's experiments at Niagara, to say nothing of the numerous experiments on the elevated railways in this country and on the Central London Railway in England, are examples where accurate results have been obtained as regards the relation of the various physical forces of moving train.

Professor Lanza's statement that the train must be under service conditions when the measurements are made is one of importance, and he appreciates that a dynamometer excludes the head air resistance and therefore mentions that power must be taken from the prime mover if this is to be included. He mentions inaccuracy introduced in using a chronograph dynamometer. I believe that this instrument is as accurate as results obtained by indicator cards. Also, it was pointed out that an average of a series of results from a chronograph will eliminate the errors of inertia of the pointer just as well as Professor Lanza's suggested method of calculation over five miles of track. The average of five miles of readings on the chronograph would probably check very well with resistance calculated on five miles of track according to Professor Lanza's suggestion.

Professor Lanza's statement with reference to my use of the Eastern Railway of France test is entirely outside of anything presented in the paper. The last paragraph of section 4 and section 5 gives certain conclusions drawn from the form of the formula, and nothing is mentioned with reference to absolute values. Besides the objections mentioned by Professor Lanza concerning the method of taking these French tests, an objection which would overbalance them all would be that the construction of cars and locomotives were different from those used in this country.

Professor Lanza's statement that it is manifestly incorrect to give train resistance in pounds per ton is a manifestly incorrect statement. Question as to whether resistances given in total pounds or pounds per ton weight of train is not one of correctness or incorrectness, but one of convenience. It is acknowledged by all engineers that a portion of the train resistance is independent of the weight or length of the train, and also that a portion of the train resistance is proportional to the weight or length of the train. On this account, in any formula you must have some term which contains the weight or length of the train. The air resistance on the head and stern of the train is independent of the weight or length, and therefore, if the resistance is given in pounds per ton, this air resistance would vary inversely as the weight of the train, whereas if the air resistance were given in total pounds, the term would be independent of the weight of the train. Again, the track resistance which is the resistance due to the wheels passing over the track is proportional to the number of wheels passing, which are with a uniform train proportional to the weight of the train. Consequently, the formula giving track resistance in pounds per ton would be independent of the weight of the train, whereas a formula giving the track resistance in total pounds would be proportional to the weight of the train.

The statement that the resistance of a train of empty freight cars does not bear to the resistance of the same train loaded, the ratio of their weights is perfectly true, but does not argue against a resistance formula giving resistance in pounds per ton. It does argue, however, for a rational train formula. The reason for the variation is that the coefficient of journal friction and track friction are different, due to the different conditions, and the only way of making a formula correspond with results, is to have proper coefficients apply. This is only possible where the various factors of the resistance are so segregated that it is possible to modify by coefficient that portion of the resistance which is changed by the change in conditions.

Paucity of experimental results on train resistance, especially at high speeds, is apparent to all, and I believe that a reason for this is that the functional relation of the different variables has not been sufficiently well appreciated in order that experimental work can be carried out intelligently. It was largely to aid in this matter that this paper was presented, and it is believed that where the proper relation of the variables is appreciated that results of experiment can be more easily tabulated, and therefore become sooner available in actual engineering work.

The points of difference in the formulæ presented in the above paper are largely in the third term. It is believed that this third term should have an exponent between 1 and 2, and nearer 2. It is believed that this term should have a coefficient, which should be the sum of two coefficients, one of which should have in the denominator a variable proportional to the weight or length of the train.

No. 983.*

THE BURSTING OF EMERY WHEELS.

BY CHARLES H. BENJAMIN, CLEVELAND, OHIO.
(Member of the Society.)

1. SEVERAL years ago the writer was consulted regarding some points of a case in litigation occasioned by the bursting of an emery wheel and the resulting death of a workman. The question to be decided was whether the wheel was unsafe at the speed recommended by the makers, or whether the accident was due to the carelessness of the operator.

As it was just then an off year for experiments on fly-wheels there seemed to be no good reason why the same medicine could not be tried on emery wheels. The apparatus already described in former papers read before this Society, with some slight alterations, was adapted to the new requirements, and in the spring of 1902, fifteen wheels of various makes were tested to destruction.

2. For the actual details of the work credit is due to Messrs. Chandler and Krueger of the class of 1902, Case School of Applied Science. Most manufacturers of this class of wheels test them for their own information, but the results are not generally given to the public; the writer knows of no published data on this subject. At the Norton Emery Wheel Works, all wheels are tested before leaving the shop at a speed double that allowed in regular service, and occasionally wheels are burst to determine the actual factor of safety.

3. Emery-wheel accidents are not uncommon, but can usually be traced to the carelessness of the operator. One common cause of failure is allowing a small piece of work to slip or roll between the wheel and the rest. The writer was once present at an occasion of this kind, and although he fortunately was not in the plane of rotation, he has never forgotten his sensations.

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

4. The wheels selected for the experiments were all of the same size, being sixteen inches in diameter by one inch thick, and having a hole one and one quarter inches in diameter.

The object of the experiments being to determine the bursting speed of such wheels as are actually on the market, emery wheels

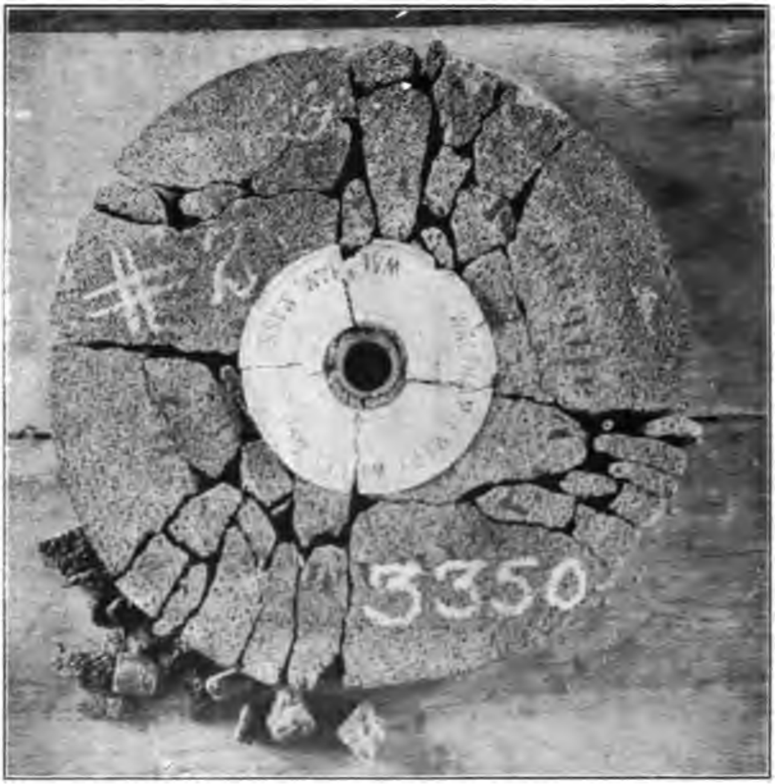


FIG. 149

were obtained through various outside parties without indicating to the agents or manufacturers the use to be made of them.

5. In this way wheels of six different makes were obtained, the label on each wheel showing usually the maker's name, the grade number or letter, the quality of emery and the speed recommended for use. As shown in the table of results, the working speed varied in the different wheels from 1,150 to 1,400 revolu-

tions per minute, the average being about 1,200 revolutions per minute. For a diameter of sixteen inches this corresponds to a peripheral velocity of about 5,000 feet per minute.

The table also shows that the fineness of the emery varied from ten to sixty, the average being about thirty.

TABLE.

No. of Test.	Grade Mark.	No. of Emery.	Working Speed.		Bursting Speed.		Speed Ratio.	Factor of Safety	Remarks.
			Revs. per Minute.	Feet per Minute.	Revs. per Minute.	Feet per Minute.			
1	4.5	20	1,200	5,030	3,100	13,000	2.58	6.67	
2	4.5	20	1,200	5,030	3,200	13,400	2.67	7.14	
3	4.5	20	1,200	5,030	3,350	14,020	2.79	7.78	
4	Q	30	1,250	5,230	3,750	15,700	3.00	9.00	
5	Q	30	1,250	5,230	2,750	11,500	2.20	4.84	
6	H	30	1,400	5,870	4,550	19,050	3.25	10.56	Wire Netting.
7	H	30	1,400	5,870	4,600	19,200	3.28	10.76	
8	O	36	1,250	5.230	4,100	17,200	3.28	10.76	
9	O	36	1,250	5,230	4,125	17,250	3.30	10.89	
10	2.5	60	1,150	4,830	2,750	11,500	2.39	5.71	
11	2.5	60	1,150	4,830	2,900	12,100	2.52	6.35	
12	M. H.	14	1,200	5,030	3,100	12,970	2.58	6.66	
13	.	24	1,200	5,030	3,800	15,900	3.17	10.00	
14	H	10-12	1,200	5,030	4,100	17,200	3.42	11.70	Vulcanized Rubber.
15	H	10-12	1,200	5,030	4,350	18,200	3.62	13.10	

6. The wheels were held between two collars, each six and one-eighth inches in diameter and concaved, so as to bear only on a ring three-fourths of an inch wide at the outer circumference.

The method of testing, and the apparatus used were precisely similar to those described in the paper on "The Bursting of Small

FIG. 150.

Cast-iron Flywheels" in vol. xxiii. of the *Transactions* of this Society, to which reference is here made for illustrations of the apparatus.

The table shows the results of the experiments in detail, and needs but little explanation. The illustrations, Figs. 149 to 152*c* show the characteristic fractures, and the appearance of various wheels after bursting.

7. Wheels numbered 1, 2, and 3 were of one make, and show a remarkable uniformity in strength. (Fig. 149.)

Nos. 4, 5, 8, and 9 were all made by one firm; the two latter wheels were of finer grain than the others, and show a correspondingly greater strength. (Figs. 150 and 152.)

FIG. 151.

Nos. 6 and 7 contained a layer of brass wire netting imbedded in the emery, and were about one-third stronger than the average of the ordinary wheels. (Fig. 151.)

The wheels numbered 10 and 11 were the weakest among those tested, but have an apparent factor of safety of between five and six. (Fig. 152*a*.)

Nos. 12 and 13 of still another make burst at about the average speed. (Fig. 152*b*.) Wheels Nos. 14 and 15 were so-called vulcanized wheels, containing rubber in the bond, and intended for particularly severe service. These showed, as was expected, rather more than the average strength. (Fig. 152*c*.)

8. An examination of the last two columns in the table shows

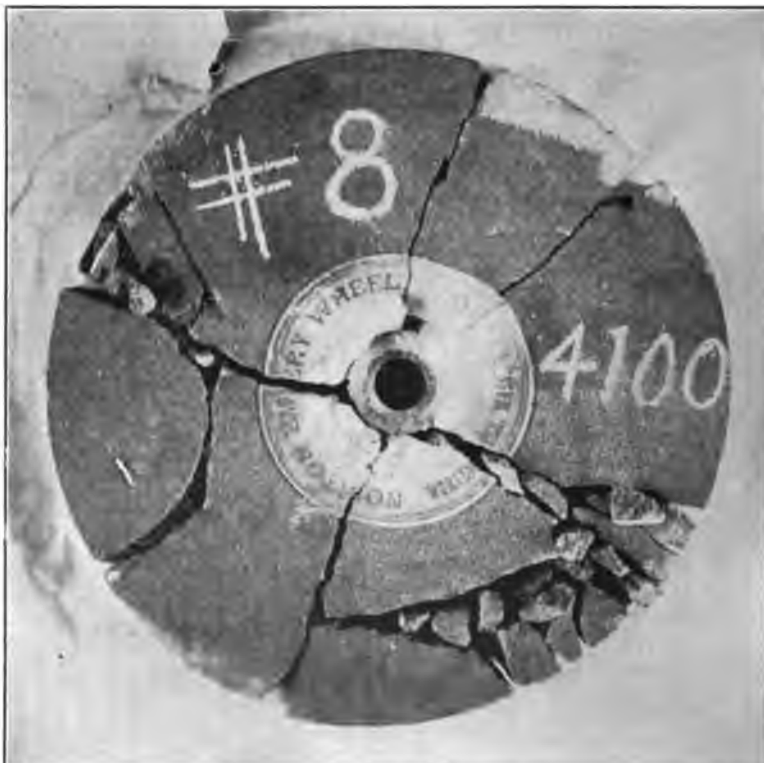


FIG. 152.

that the wheels burst at speeds varying from two and one-quarter to three and three-quarters the working speed, and accordingly had factors of safety, varying from five to thirteen.

It is then apparent that any of these wheels were safe at the speed recommended, and would not have burst under ordinary conditions. At the same time, considering the violent nature of the service and the shocks to which they are exposed, it would seem that the factor of safety for emery wheels should be large. In comparison with those generally used in machines, a factor of eight or ten would seem small enough.

It may also be said that such a variation in strength between wheels of the same make and grade, as for instance, that between

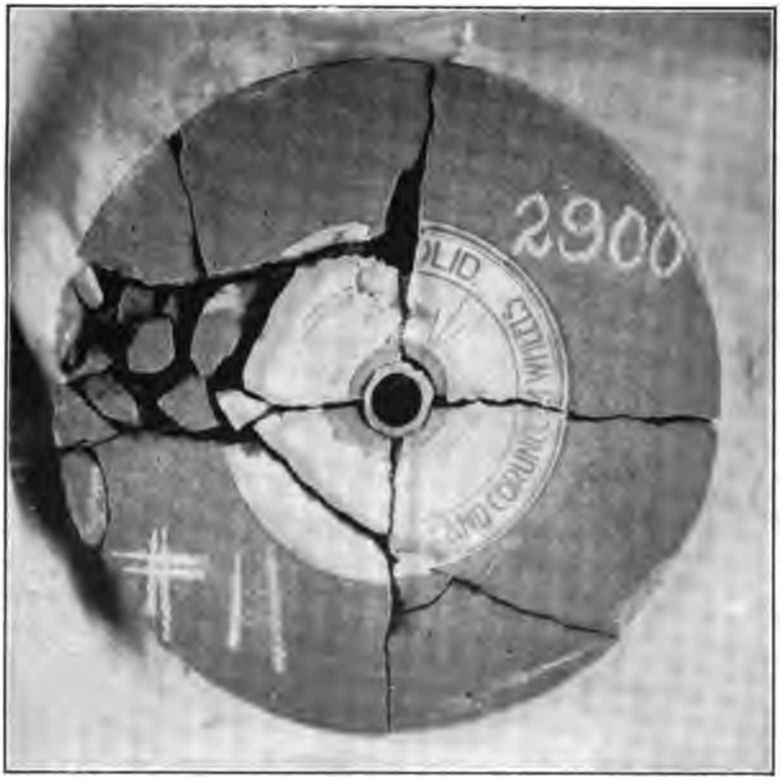


FIG 152*a*.

Nos. 4 and 5, indicates a lack of uniformity which causes distrust.

9. The fractures were in the main radial, as may be seen from the cuts, the wheel splitting in three, four or five sectors as might chance.

It may be assumed that these radial cracks started from the rim where the velocity and stress were greatest, but it is a fact

Fig. 152b.

worthy of notice that in nearly every instance the cracks radiated from points where the lead bushing projected into the body of the wheel.

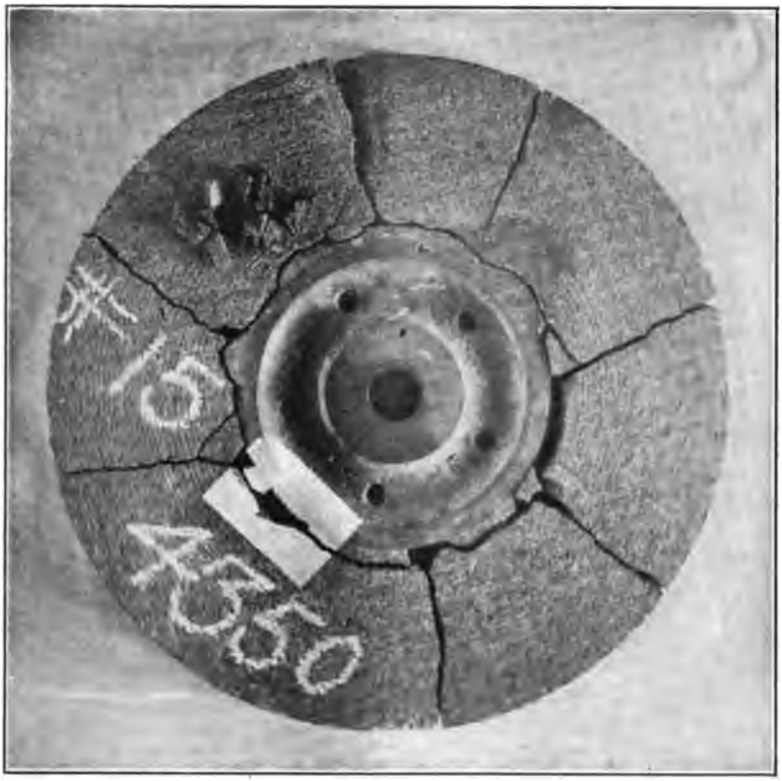


FIG. 152*c*.

In this connection the writer would be glad to learn of any published discussions on the centrifugal stresses in rotating discs as distinct from those in thin rings.

DISCUSSION.

Mr. Cole.—I would call attention to the fact that the factor of safety which is given on page 965 of the paper is based not on one speed for all the wheels mentioned, but is based upon the speeds given in the columns called " Revolutions per minute," which, under lines 10 and 11, is but 1,150 revolutions per minute, whereas in others it is 1,200, 1,250 and 1,400. So that a person looking down the column "Factor of safety" without looking back to "Revolutions per minute" would think that the strongest wheels were not as strong as would show by taking, for instance, the basis of 1,200 revolutions for all the wheels.

Another thing, with reference to these dove-tailed clamps or collars. Some years ago I obtained a patent on that device. The patent has since expired; I never used it myself, but it has been used by other makers. I have found that in several cases there is a temptation to make a weak wheel and depend upon these collars. There have been accidents with which I have been familiar where not only has the wheel broken, but the collar as well.

Mr. C. V. Kerr.—I was especially struck with the last sentence in the paper regarding the published discussions on the centrifugal stresses in rotating discs as distinct from those in thin rings. I did not get a copy of the paper until this morning, and so I have not had an opportunity to get what I would like to say in the proper shape.

For thin rotating rings, for steel the stress in pounds per square inch is $0.105v^2$, for cast iron, $0.097v^2$; for solid rotating discs, for steel the stress will be $0.035v^2$, and for cast iron, $0.032v^2$, where v is the rim velocity in feet per second.

Theoretically, the stress for solid rotating discs is just one-third what it is for a rotating ring. The reason is that the inner layers of metal in the disc give support to the outer layers.

Mr. Calder.—I was employed at one works where one of the workmen was killed by the bursting of an emery wheel, and we began to look around to see what could be done as a safeguard against such accidents in the future. One thing that we did, was to provide a guard around the wheel. We got the maker of the wheel to make a wheel slightly convex on the side, and we used a washer which was concave. The result was, as Professor Benjamin shows in his paper, that, when a break comes from a radial direction, the pieces break, it is true, but they cannot fly out and cause injury.

Mr. H. A. Richmond.—Professor Benjamin refers to the variation in strength of different emery wheels, but fails to mention one very potent factor in this variation. I refer to the grade of hardness. As is well known, emery wheels are made in a variety of grades (each suitable for a particular class of grinding), this variation in hardness being effected principally by an increase or decrease in the proportion of bond to abrasive. Since a hard wheel contains relatively more bond than a soft one, it should be stronger, and this is found to be the fact. No very soft wheels appear to have been tested in Professor Benjamin's experiments, but numbers 10 and 11 appear from the grade marks to have been the softest, and, as stated in the paper, these were the weakest of the lot. Had wheels soft enough for surfacing tempered steel been tested, a much wider variation in strength would have been shown.

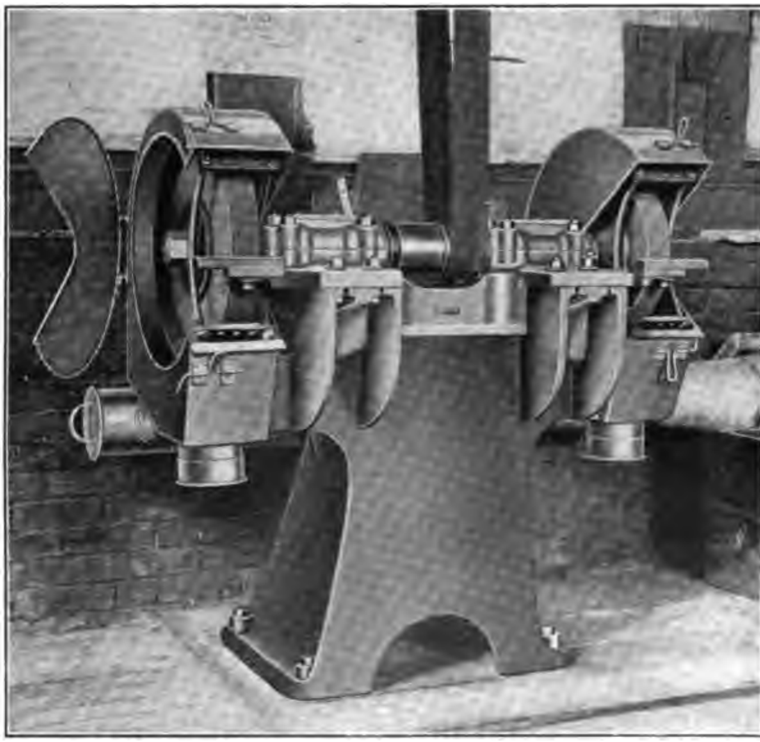


FIG. 152*d*.

I know of some wheels used for a special purpose which have to be made so soft that breakage is not uncommon, even though they are used under the best possible conditions.

I hope Professor Benjamin will make some further tests with special reference to the grade of hardness.

Mr. Waldron.—This paper, undoubtedly, fills a long-felt want, by giving reliable data relating to the actual strength of emery wheels. During the past year this proposition has been brought home to the writer most seriously, as, in the Yale and Towne

Works, we have had three emery wheels burst in our iron foundry grinding room, from different causes. In one case a man was killed; in the second, another was seriously injured; while in the third, outside of a large dent in the ceiling, no injury was done.

These three accidents, occurring within a period of six months, naturally raised the question as to what caused them. The writer was directed to investigate the causes of trouble, and to devise remedies, and has established a method whereby, whether through the carelessness of the men or from any inherent fault of the wheels or their mountings, accidents as serious as the above should be avoided.

For the benefit of those who are interested, and of humanity at large, and as a fitting supplement to this excellent paper, the conclusions so reached are reported as follows:

(1) That almost invariably, as stated by Professor Benjamin, these accidents are due to the carelessness of the operator.

(2) That grinding machines, as a class, are given less attention than any other machines in a factory.

(3) That comparatively few manufacturers provide protective guards for their operators.

(4) That improper rests are probably the cause of more accidents than any one thing.

(5) That a tendency prevails to speed up large and heavy wheels, often improperly balanced on too light a frame.

NOTICE.

MACHINE NO. 2086

The Speed of this Machine is 1500 rev. per min. Wheels Larger than 16 inches Diameter MUST NOT be used upon it.

THE YALE & TOWNE MFG. CO.

FIG. 152e.

(6) That it is the tendency of almost every operator to use the emery wheel truing device, and it seems to have a special attraction for a new man in the business.

(7) That it is the tendency of all piece-work operators in grinding-rooms to exceed the working speed limits of the wheels which they use.

To avoid accidents, the following plan was adopted:

1. All grinding machines throughout the entire factory had their speeds scheduled, numbers given to the machines and a record of the same kept in the office.

2. All requisitions for emery wheels must state on them the number of the machine on which the wheel is to be used. The list in the office is then referred to, and, if the size of this wheel comes within the proper limits of periphery speed for the particular machine, the requisition is passed to the Purchasing Agent.

3. Light steel guards (obtainable in the open market) have been placed on all the machines, so far as practicable.

4. A special machine has been designed for 16-inch wheels, and extra heavy base, with very large spindle and ring oiling bearings, bolted to 4 by 6-inch timbers, laid in concrete. This is provided with substantial rests, and one speed only is provided for each machine. After the wheel is worn down to a certain diameter, it is transferred to the next machine, which makes a greater number of revolutions per minute. Back of each of these machines a placard is posted, on which is stated the number of revolutions per minute and maximum diameter of wheel which is permitted to be used on it. Grinders with cone pulleys are being discarded.

5. The emery wheel dresser is kept under lock and key, and *one man* is held responsible for the truth and balance of all wheels.

6. Use of wheels with large holes (say above 2-inch holes for 16-inch wheels) has been discontinued.

With these precautions, it has been found that large wheels can be easily speeded to 6,000 feet per minute, at the periphery, with perfect safety to the operator and a corresponding increase in production.

In the light of these tests by Professor Benjamin, it is evident that a liberal factor of safety has been provided by reputable makers of emery wheels, and that, as a general proposition, the bursting of emery wheels is directly traceable to carelessness on the part of operators, and indirectly traceable to improper mountings, badly designed and poorly adjusted rests, improper and ignorant handling of the emery wheel dresser.

No. 964.*

A COMPARATIVE OIL TEST.

BY WILLIAM F. PARISH JR., BOSTON, MASS.
(Junior Member of the Society.)

1. OF all the methods of testing lubricating oils there is none that is quite so interesting, or that will give so graphically and in so short a time the effect of an increase or a decrease in frictional resistance as a dynamometrical test upon a cotton-spinning frame of the ring type.

It is the purpose of this paper to describe in detail a short but very conclusive test of this nature.

The test was made for the purpose of showing the relative efficiency of two different grades of oil, both of which were made for the same kind of service—*i.e.*, spindle lubrication.

One of the oils has been tested several hundred times in the manner outlined in this paper, and the main characteristics shown here have been recorded in every test. These tests have been conducted in every country where the spinning frame is in use, and the reduction in power shown by this oil has ranged from 4.2 per cent. as high as 32.6 per cent.

The same general system is employed in making these tests, varying in such details as duration of test, number of readings, etc. Some tests cover a week on each oil, which is necessary if a work load and atmosphere variable is to be averaged.

In the test here given the work load was taken for half an hour just previous to doffing, which is done when the bobbins are full, and for the same length of time when the bobbins were just beginning to fill. Readings were secured with both oils under these conditions.

After these preliminary readings, others were taken upon bare spindles, *i.e.*, the bobbins were taken off and the delivery of rov-

---

* Presented at the Saratoga meeting (June 1903), of the American Society of Mechanical Engineers, and forming part of Volume XXIV., of the *Transactions*.

ing stopped by throwing out the two back drawing rolls, leaving on the front rolls only, which with the traverse motion, spindles and cylinder constituted the test load, uninfluenced by any variable factor of work.

The oil used influenced approximately 92 per cent. of this entire load.

Spinning Frame.

2. The test was made at the Union Cotton Manufacturing Company's mill No. 2, Fall River, Mass., U. S. A., upon a Whitin frame of the following general specifications:

288 Medium Gravity Spindles.
¾-inch Whorl.
7-inch Cylinder.
14-inch Driving Pulley.
1⅜-inch Ring.
17 per cent. Traveler.
5½-inch Filling traverse motion.

This frame was working under the following conditions:

40's filling.
27.5 lbs., weight of 288 full bobbins.
14 " " " 288 empty "
13.5 " yarn to a full frame.
90 bands to the pound.
2.31 lbs. average band pull.

The spindles were of the "bath" or "submerged type," and ran in an uncovered iron bolster which was fitted into the base.

These bases hold the oil, about 5 pints being required on a frame of this size to fill them full. While the frame is in operation oil is added to that in the bases at intervals of from two to seven weeks. Oil that has to be confined in these bases and operated upon at the required spindle speed, which in the present case was about 8,400 revolutions per minute, must necessarily be properly constructed. Any tendency of an oil to gum or leave a deposit, to break down or wear out will show up very quickly under these working conditions.

The oil which showed the lowest horse-power reading, and herein referred to as *V*, was first used in August, 1902, having at that time displaced the oil herein referred to as *X*.

The test, when started, was made upon the frame exactly as found, no preparation whatever being made. Part of the oil in the spindle bases had probably been there for the greater part of six months.

In order to ascertain whether or not this *V* oil had lost any of its efficiency a check test was made with all conditions the same, except that the spindle bases had been pumped out, the bolsters and spindles washed with naptha, and new oil placed in the bases.

These two tests vary only $\frac{8}{100}$ of a horse-power, showing that the oil had lost none of its efficiency through continued service.

Instruments.

3. An exceptionally sensitive Emerson dynamometer was used. This is a compact instrument, which is fitted to the end of the drum shaft, outside of the loose pulley.

The instrument for descriptive purposes is practically in two parts.

One part is fastened to the shaft and carries the arms, levers, reducing links, revolution counter, and the quadrant.

The other part, fitted over a sleeve on the back, is practically a dog plate engaged by two studs in the arms or disk of the loose pulley.

In operating the instrument the belt is thrown from the loose to the tight pulley. After the frame is up to speed, and the loose pulley is carried at this same speed, a sliding bolt is thrown from the instrument proper and is caught by one of the ears on the dog plate which is fastened to the loose pulley.

This makes the loose pulley a tight pulley, and as the belt is thrown over on the loose pulley, the weight of the frame is carried through the levers in the instrument and is registered on the quadrant.

In connection with this dynamometer a tachometer is used, but in the present case it was found impossible to secure as great accuracy as was desired, owing to the difficulty in estimating the average movement of pointer to within two or three revolutions.

A Guggenheim tachoscope was therefore used. This instrument, which is of Swiss manufacture, is a clever combination of a stop-watch and a revolution counter, both of which go into action at the same time.

Horn's tachometer, made in Germany, was used for registering spindle speeds, 5 spindles being selected and their average speed taken.

A special spiral spindle-base thermometer, a wet and dry bulb hygrometer for ascertaining relative humidity, and a Draper band tension scale completed the equipment.

Conclusion.

4. Before considering the results shown by this test it may be well to outline the various effects which should result from the use of a spindle lubricant.

The spindle is driven by a band made of twisted roving. In the present case 90 of these bands weighed 1 pound. These bands are put on over the drum and around the whorl of the spindle, and are tied so that they exert a pull of possibly 5 to 7 pounds. After running they stretch to different tensions, averaging on this test 2.31 pounds.

Under this pull the spindle will be driven at a certain loss or slippage which is proportional to the amount of fluid or abrasive resistance around the spindles.

Resistance, either fluid or abrasive will produce heat.

Extra spindle resistance with the consequent higher driving power required will produce greater belt slippage.

Assuming a condition produced by a poor lubricant, and substituting one more adapted to the work, the result should be a lessened spindle resistance, the consequent heat should be reduced and the slippage of band and belt should be lessened, allowing both to drive nearer to the maximum or theoretical speed, thereby increasing production.

In the present case the horse-power to drive the frame was reduced 14.08 per cent.

The actual temperature or rise of spindle base was reduced 2.79 degrees Fahr.

The cylinder speed increased 3.6 revolutions per minute, and spindle speed 60 revolutions per minute.

This checks conclusively by all the various effects the reduction in power caused by more perfect lubrication.

5. The temperature of the room was favorable to the oil which made the poorer showing, as it was somewhat warmer.

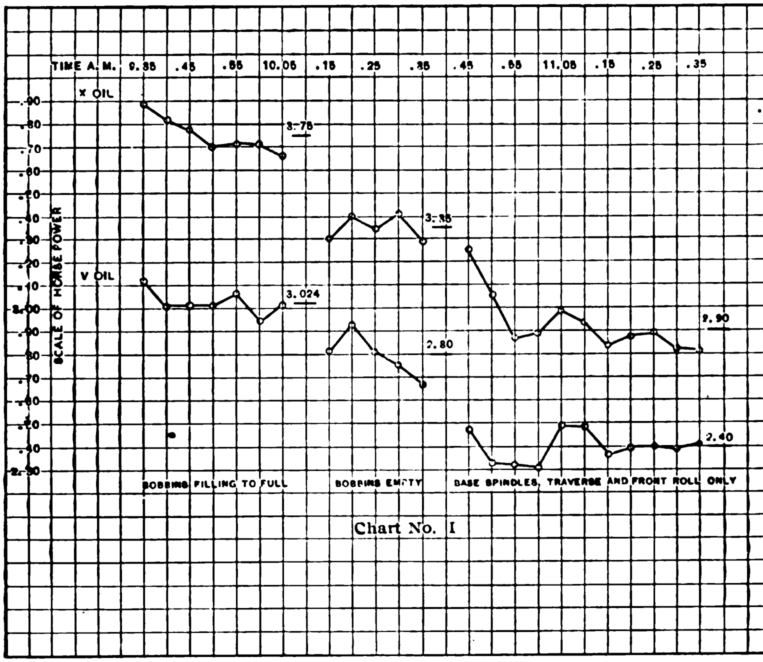


FIG. 153.

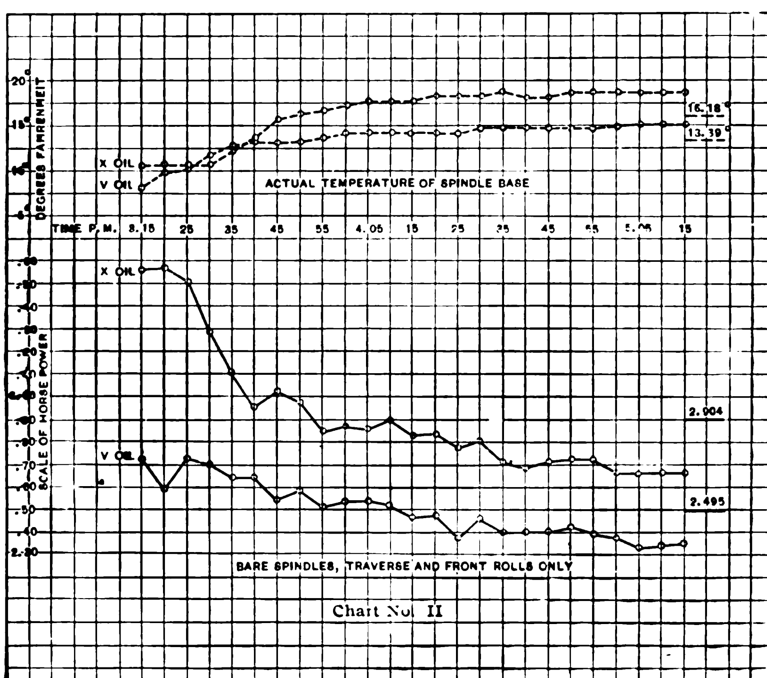


FIG. 154.

Explanation of Charts.

Chart No. I.

Beginning with the first reading of the lower line, representing power indicated under V oil with the frame as found.

The frame was started cold, spinning with bobbins filling, to full.
Average horse-power 3.024

The frame was then doffed. Bobbins empty.
Average horse-power 2.80

Frame with bare spindles, traverse motion and front roll only.
Average horse-power 2.40

The upper line represents the power required with X oil under the same conditions except the bases had been pumped out, bolsters and spindles cleaned with naptha before the X oil was introduced.

Frame cold. Spinning with bobbins filling, to full.
Average horse-power 3.75

Frame doffed. Bobbins empty.
Average horse-power 3.35

Frame with bare spindles, traverse motion and front rolls only.
Average horse-power 2.90

Chart No. II.

This shows tests made for two hours on each oil upon bare spindles, traverse motion and front roll only. The spindle bases were pumped out and bolsters and spindles cleaned in naptha previous to each test before the oil was placed in the spindle bases.

The upper dotted line shows the actual rise in temperature as shown by the spindle base thermometer during two hours run on X oil, starting cold.
Average ....16.18° Fahr.

The lower dotted line shows the rise in temperature with V oil, starting cold.
Average..13.39° Fahr.

A reduction of....................................... 2.79° Fahr.

The upper full line shows the power required with X oil, starting cold.
Average horse-power for two hours...................... 2.904

The lower full line shows the power required with V oil, starting cold.
Average horse-power for two hours...................... 2.495

With work conditions the same V oil shows a reduction in power of ....14.08 per cent.

COMPARATIVE TABLE OF AVERAGES.

	X Oil.	*V Oil.*	*Difference.*
Horse-power	2.904	2.495	14.08 per cent.
R. P. M. cylinder	963.7	967.3	3.6 R. P. M.
R. P. M. spindle	8,380	8,440	60 R. P. M.
Temperature spindle base, ° Fahr.	93.44	88.05	
" room "	77.26	74.66	
" actual "	16.18	13.39	2.79° Fahr.
Relative humidity per cent	45.22	50.02	
Band pull	2.31	2.31	

No. 985.*

TURBINE FLOW RECORDER.†

BY C. M. ALLEN, WORCESTER, MASS.
(Junior Member of the Society.)

1. WHEREVER water-power is sold it is customary to use the turbines as meters to keep an accurate account of water used by different consumers.

2. The usual method employed is to obtain daily two or three records of the existing conditions under which the turbines are working, the most important items being the gate opening and head. The speed is usually a constant factor. Then from tables and curves made up from previous tests of those turbines, either at the Holyoke flume or on the ground, data are obtained from which to compute with a fair degree of accuracy the actual discharge. This is referred to a given head and thence reduced to mill-powers, the values of which vary with the locality. For instance, a mill-power at Holyoke is 38 cubic feet per second discharging under a head of 20 feet, corresponding to 85.2 theoretical horse-power. A mill-power at Lowell is 30 cubic feet per second discharging under a head of 25 feet, corresponding to 86.4 theoretical horse-power, while at Minneapolis a mill-power is 30 cubic feet per second discharging under 22 feet, corresponding to 75 theoretical horse-power.

3. The time of taking the daily observations is continually changed, and in the long run it is supposed that an approximate average will be obtained.

4. The object in designing this turbine flow recorder was in part to do away with the manual labor connected with the system just mentioned, as well as to get, if possible, a more accur-

---

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions.*

† For further references on this subject, see *Transactions* as follows:
No. 583, vol. xiv., p. 676: "Water Measurements." F. Lux.
No. 184, vol. v., p. 63: "Tilting Water Meter." J. C. Hoadley.

ate record of the actual discharge in that readings are registered much more frequently; these being taken once a minute instead of two or three times a day. This device records automatically the total quantity of water discharged by the turbine. It really makes a water meter out of the turbine, using the vanes of the turbine as the vanes of the meter, and readings are taken from

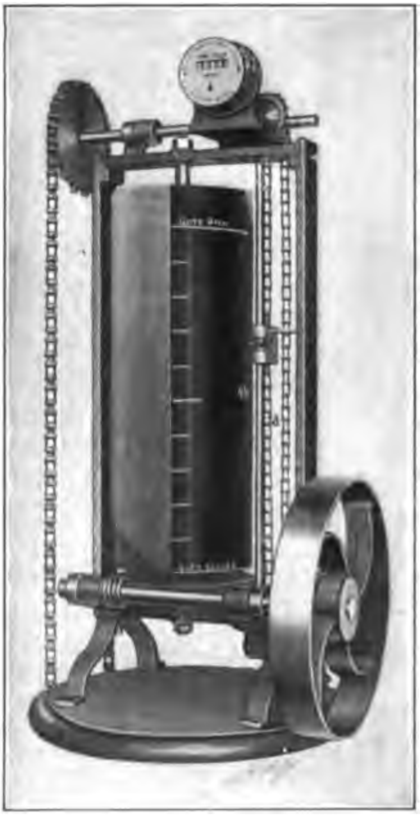


FIG. 155.—FRONT VIEW OF SINGLE CYLINDER RECORDER.

the dials in the same manner as from the ordinary water meter. In other words, this device records the total quantity of water passing through a given turbine with a variable gate opening and acting under a variable head. In places where the head is practically constant a single-cylinder type of recorder is used, which deals only with a variable gate opening. In places where the head varies sufficiently to be taken into account a second cylinder is used and compensates the final reading for the varying head. In places where the head varies the important question is not how much water is used alone, but how much water and under what head, or, in other words, how much available power is supplied. This last question can be answered by the two-cylinder type of recorder, provided a record of the head is also kept, although a third type of recorder has been devised

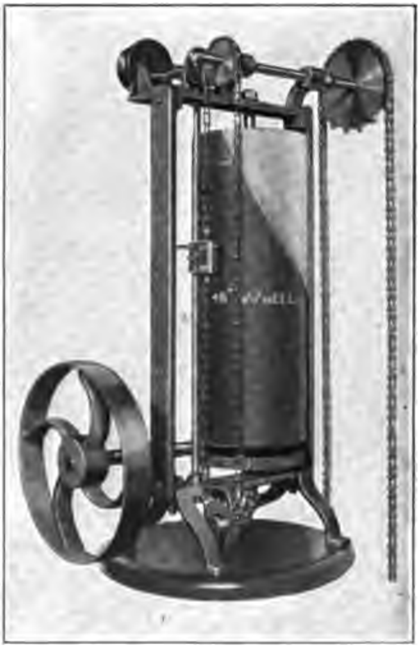


FIG. 156.—REAR VIEW OF SINGLE CYLINDER RECORDER.

which, instead of registering cubic feet discharged, gives directly mill-power hours.

5. The machine is best described by considering first the single-cylinder type for unvarying heads, shown in front and rear views in Figs. 155 and 156 and in position connected with a horizontal shaft turbine in Fig. 157.

6. It is obvious that were the load on a turbine such as to call for uniform speed at full gate, a counting register driven by the wheel could be made to give a correct record of the amount of water used, and that this register might be graduated from a

test of the wheel as to give its readings in cubic feet of water. Were the speed constant and the discharge proportional to the gate opening the correct reading for, say, half gate would be obtained by stopping the register one-half of the time and for three-quarters gate opening by stopping the register one-quarter of the time. This is the essential principle of the machine, but, as a matter of fact, the discharge is not proportional to the gate

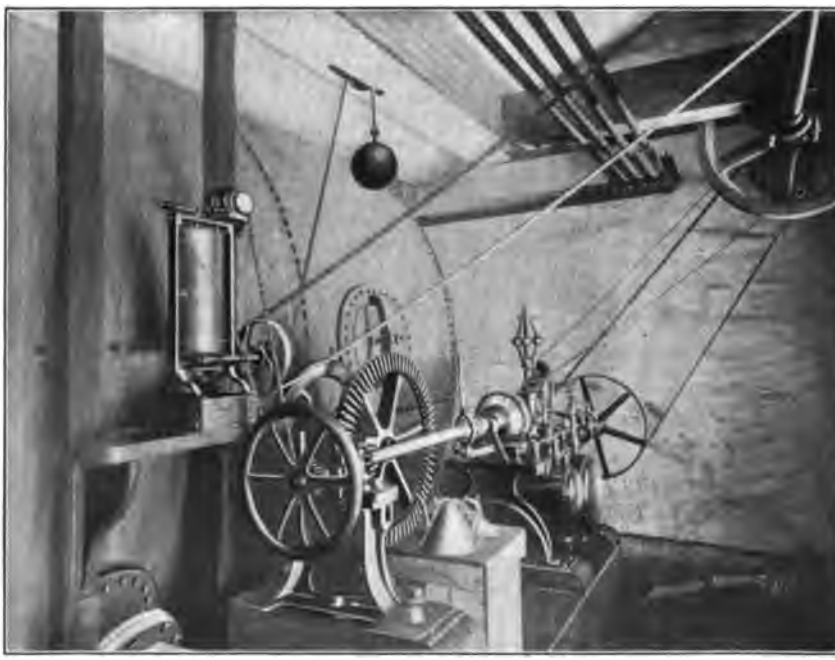


FIG. 157.—SINGLE CYLINDER RECORDER CONNECTED TO TURBINE.

opening, being, for half gate, materially in excess of half that due to a full gate, and allowance must be made for this.

7. Referring to Figs. 155 and 156, a vertical cylinder will be seen having at its bottom a worm wheel which is driven by a worm (slipped to the left and out of gear in Fig. 155) which, in turn, is driven by the turbine, the proportions of the parts being such that the cylinder makes one complete turn per minute. This cylinder drives the register above it by the vertical splined shaft at the right of the cylinder in Fig. 155 and at the left in Fig. 156. Upon the cylinder is a raised surface extending the whole length

and having one edge vertical, as seen in Fig. 155, but the other edge curved, as seen in both illustrations. The profile of this curve is such that, the vertical distance from the bottom of the cylinder representing the gate opening, the circumferential length of the raised surface at any distance above the bottom represents the discharge of the wheel at a corresponding gate opening, as

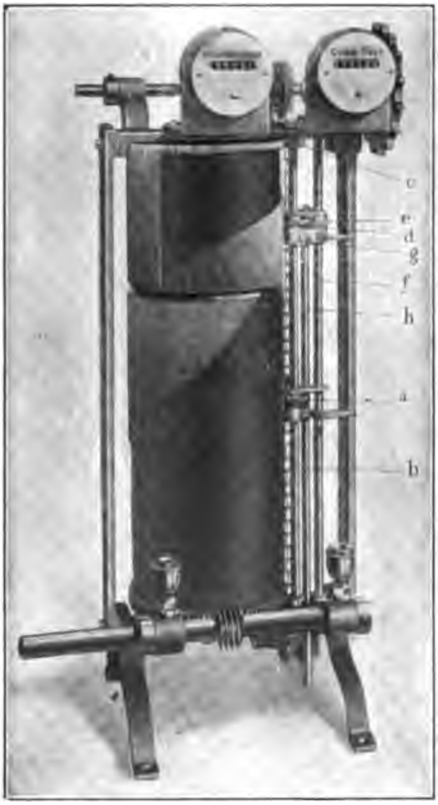


FIG. 158.—DOUBLE CYLINDER RECORDER.

obtained from an efficiency test of the wheel. The splined shaft is driven by a roller *a* carried in a housing which slides upon the shaft, the roller driving the shaft and register above whenever it is in contact with the raised surface, the vertical position of the housing and roller being determined by connection with the gate shaft, which, in turn, is controlled by the governor. To insure positive driving of the register whenever the roller is in contact with the raised surface, both have grooves or teeth cut upon them which are fine enough to insure engagement without difficulty.

8. The connection of the recorder to the turbine will be clear from Fig. 157, the vertical cylinder being driven by the belt from

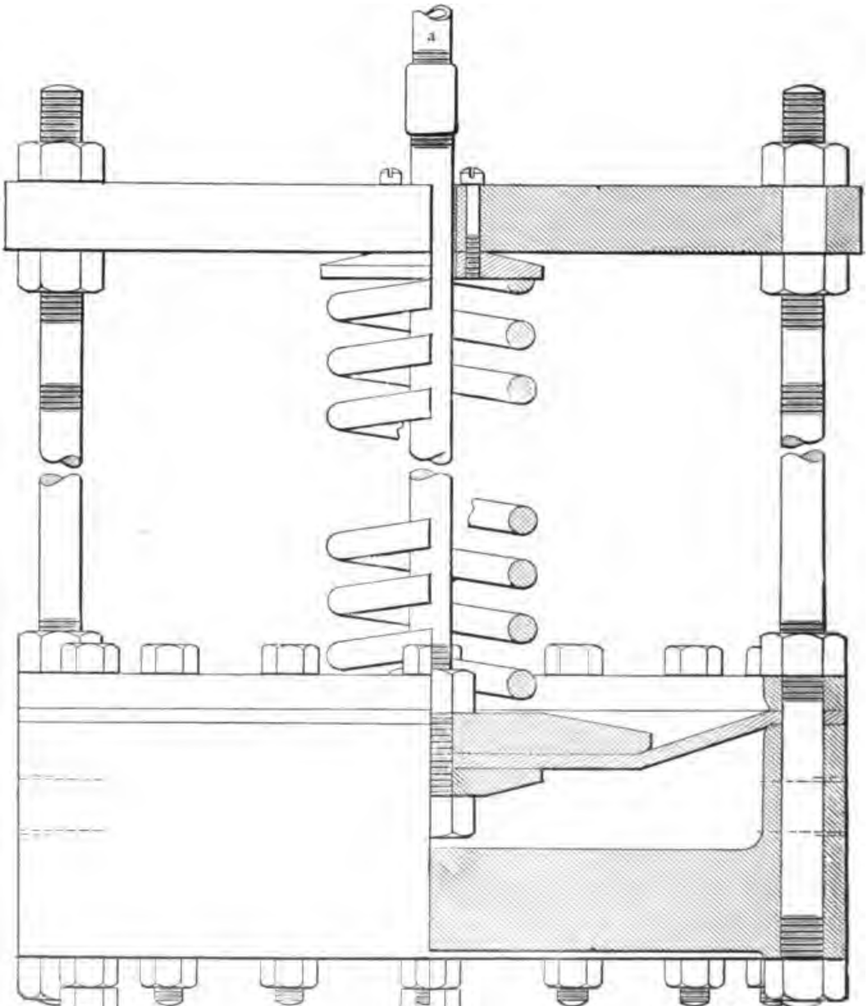


FIG. 159.—TAIL-RACE PRESSURE DIAPHRAGM.

the overhead shaft, while the housing and roller are connected to the gate shaft by sprocket wheels and chain in such manner that, as the governor opens the gate, the roller is raised, while as the gate is closed the roller is lowered.

9. In the second form of the machine shown in Fig. 158; which applies to wheels operating under both variable gate opening and variable head, the vertical cylinder of the machine described above does not turn the register directly, but, instead, drives a second upper cylinder which in turn drives the register. The second cylinder has a raised driving surface similar in general character to that of the first one, the profile of which represents the varying discharge under variations of head, the register driving roller of this cylinder being adjusted vertically by a pressure diaphragm submerged in the tailrace. The action of the two raised surfaces are thus compounded in the final readings of the register.

10. In Fig. 158 the roller *a* is adjusted vertically by connection with the gate shaft as already described. It drives the splined shaft *b*, which, in turn, drives pinion *c* and the upper cylinder through the complete gear at its top. The raised surface of the upper cylinder drives toothed roller *d*, which is loose upon shaft *b* and acts as an idler to drive roller *e*, which is splined to shaft *f* and is carried in a vertically adjustable housing *g*, similar to the one which carries roller *a*, the vertical position of this housing determined by its connection with the pressure diaphragm representing the head under which the turbine is working at the moment. At full head the housing *g* will be at the bottom of its movement when the raised surface is continuous and the readings will be similar to those of the first machine, the upper cylinder and wheels *d* and *e* acting as simple idlers. Should, however, the water in the tailrace rise and thus reduce the pressure on the wheel and the discharge for a given gate opening, housing *g* will be raised, and, the raised surface of the upper cylinder being at this point interrupted, a pause due to this interruption will be introduced in the movement of the register. The profile of the raised surface of the upper cylinder is plotted from tests of the wheel under varying head as the profile of the lower one is plotted from the tests under varying gate opening.

11. The register immediately above the upper cylinder is a revolution counter for the wheel. Pointers extend from the two housings to the right-hand frame upright which carries scales by which the gate opening and head may at all times be read.

12. The tailrace pressure diaphragm is shown in Fig. 159. It is submerged below the lowest tailrace level, so that the tailrace water always acts upon its upper side. The lower side is con-

nected by a tube—filled with oil to prevent freezing—with the turbine case. The net actuating pressure on the diaphragm is thus the pressure due to the difference in heads in the two sides

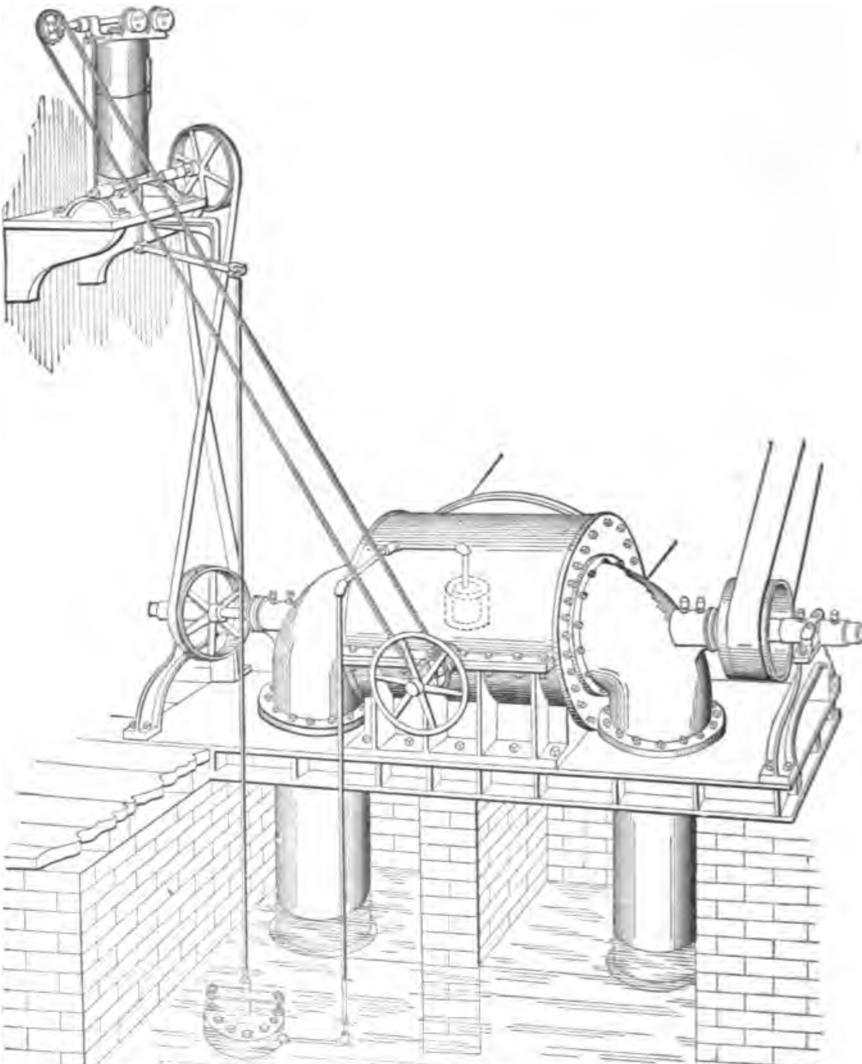


FIG. 160.—DOUBLE CYLINDER RECORDER CONNECTED TO TURBINE.

of the diaphragm. This actuating pressure is resisted by a spring, and the movement of the diaphragm is communicated by the rod *a* to the housing *g* of Fig. 158 by means of the rod *h* of

Fig. 158, as shown in Fig. 160, which also shows the connection with the gate shaft.

13. As described, the machines register the cubic feet of water passing the wheel. With a constant head this is proportional to and an index of the power consumed, but under a variable head this being no longer the case, a third modification of the machine has been devised, in which, by a change in the profile of the raised surface of the upper cylinder, the register is made to read directly in mill-power hours.

14. Tests of a sample machine designed from Holyoke tests of a turbine show variations of from a fraction of 1 per cent. to not over 3 per cent. under varying gate opening and under a head of from 30 down to 18 feet. If curves had been plotted from tests on the ground the results would practically check.

No. 986.*

AN INDICATING ANGLEMETER.

BY C. E. SARGENT, CHICAGO, ILL.
(Member of the Society.)

1. Ever since it has been desirable to operate alternating generators in parallel, the question of getting a prime mover the angular velocity variation of which shall come within the limits prescribed by the generator manufacturers, has been an important consideration. When Corliss engines were first used for incandescent direct-current lighting, many of them had such light-weight fly-wheels that an observer could count the revolutions of the engine by the variations in candle-power of the lamps. Generally speaking, the heavier the fly-wheel—other things being equal—the less will be the angular velocity variation during a rotation; but the heavier the fly-wheel the greater the first cost and the more power required to revolve it in its bearings; hence a fly-wheel just heavy enough to vary less than the maximum allowed is more economical than one of greater weight.

In order to be able to determine at sight the actual maximum variation in steam-engine fly-wheels, and more expressly in the fly-wheels of internal combustion engines with which the writer has more to do, the instrument herewith described was designed. In order to be practical, such a device must be applicable to any engine; it must be portable, easily attached, substantially built and direct-reading, and it is believed that this instrument will fill these requirements.

2. If a light pulley is driven by the engine shaft with a flexible, inelastic belt, it should vary in speed commensurate with that of the engine. If a heavy fly-wheel at a high velocity is kept in motion by a tension spring having a practically uniform pull, there should be no change from a uniform velocity during

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

a revolution of the engine. The device herein described indicates in circular measure the variation of the engine fly-wheel from a uniform velocity.

Fig. 161 is a side view of the device, which hereafter will be called an anglemeter.

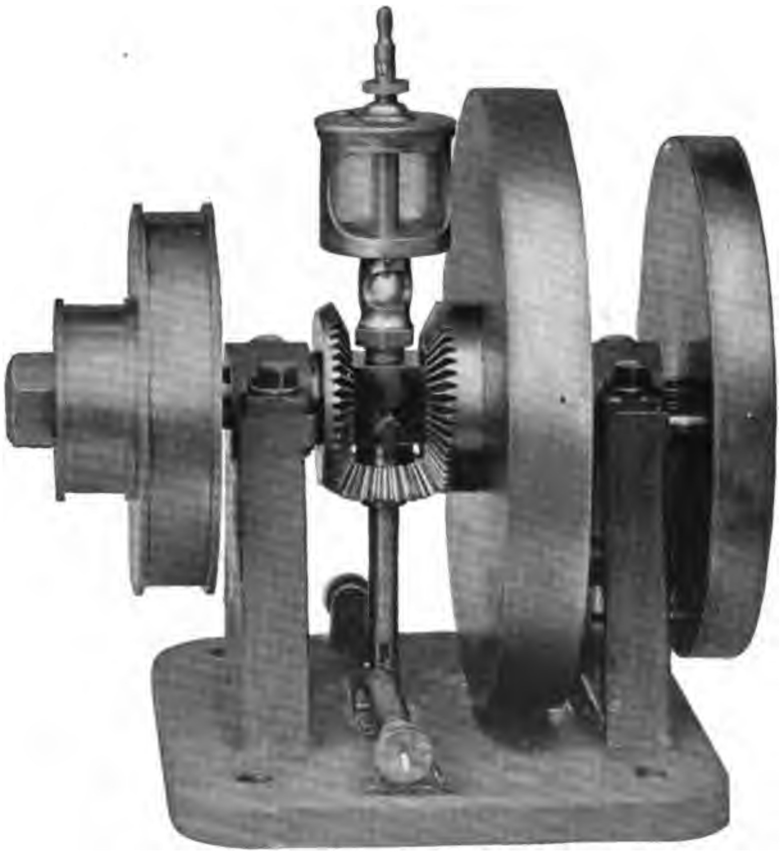


Fig. 161.

Fig. 162 is an end view showing the graduated dial and aluminum needle.

Fig. 163 is a vertical longitudinal section through the centre.

Fig. 164 an end view with the dial removed.

Fig. 165 a transverse section through centre.

3. The anglemeter consists of a heavy main frame and base, and two uprights with bearings on each which carry the moving parts.

The shaft A, Fig. 163, to which the intermediate bevel pinion axis D and the segment F are rigidly attached, carries the fly-wheel and bevel gear B, the driving pulley C and the gear E; the latter are fastened together by the feather I.

The rotation of the shaft A and the parts fixed to it, is limited by the stops K, Fig. 165. Motion of this shaft and segment F is

FIG. 162.

transmitted to the pinion G and segment F' and the pinion G', which is loose on the pin M, and carries the needle O.

This oscillating brass shaft has a small hole from end to end which, with the transverse holes, distributes oil to all working parts without waste from the one oil cup shown in Fig. 161.

The driving pulley C is made very light, with two diameters for high and slow speed engines, and is fastened to gear E by the feather I and nut P.

The axis D is held in a vertical position by the two opposed tortion springs, Fig. 165. By using two springs under tension a large movement for a small increment is obtained, and the anglemeter may be run in either direction; and when running, a proper adjustment of the tension nuts brings the needle to a vertical position on the dial. A hair spring around the pinion G', not shown in the cut, eliminates any lost motion in the multiplying gear. The anglemeter is driven by a belt from some part of the engine shaft, which through the intermediate bevel pinion and

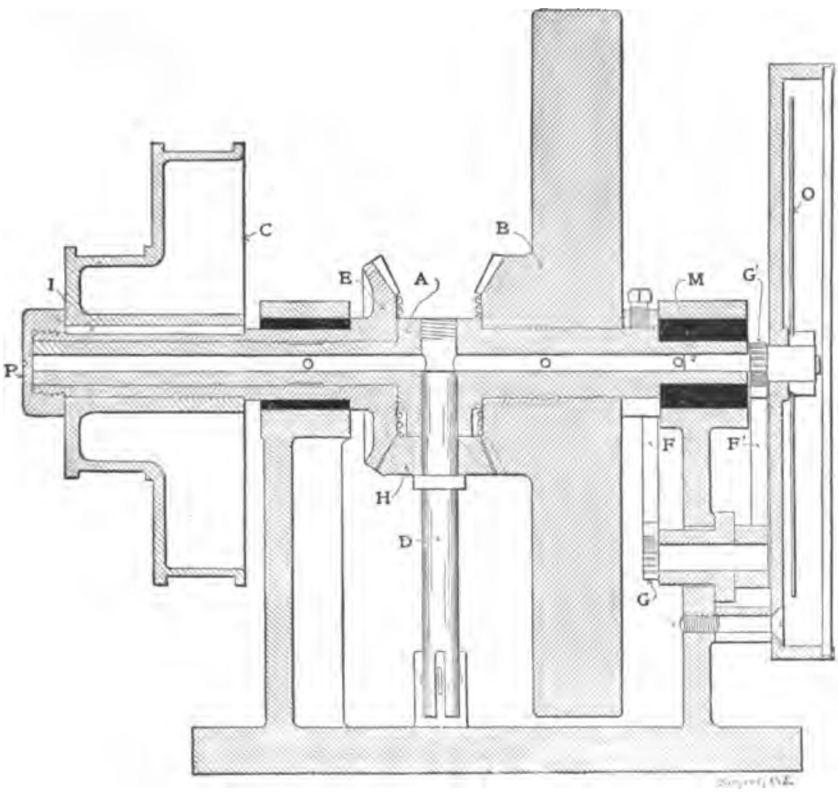


FIG. 163.

the tension springs, drives the fly-wheel in the opposite direction at a uniform velocity.

If the tension of the springs which tend to hold the intermediate bevel-pinion axis in a vertical position is equal to the pull necessary to keep the fly-wheel rotating at a constant speed, then a change in the angular velocity of the driving pulley which varies with the change of the engine speed allows the axis of the bevel pinion to vary one-half the angle of driving pulley.

4. If the diameter of the pulley on engine shaft is such that

the velocity of the anglemeter is 7.2 times faster than the engine, its angular variation during one rotation of the engine will be 7.2 times greater, and the angular variation of the axis of intermediate bevel pinion from a vertical or normal position will be 3.6 times greater than that of the engine; and the needle, which has an angular movement 100 times greater than the bevel-

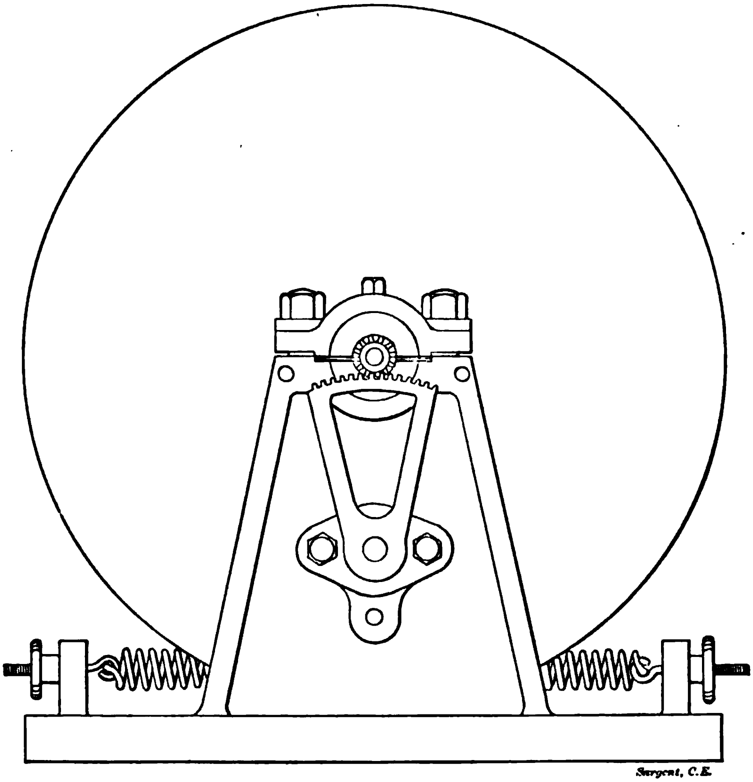


FIG. 164.

pinion shaft, will therefore have 360 times the angular movement of the engine fly-wheel from a uniform rotation. Therefore if the engine fly-wheel should vary one degree during a rotation, the needle on the dial would vary 360 degrees, or make a complete half revolution each side of the normal position.

As the dial has 360 divisions or degrees, one minute variation of the engine shaft would show six degrees on the dial, and ten seconds variation of the engine would show one degree on the dial.

5. A belted tachometer from the anglemeter fly-wheel shows a uniform speed under extreme angular variations of engine fly-wheel, which might be expected, however, when we consider that for a variation of one degree of engine the change in the length of springs is less than $\frac{1}{4}$ of an inch, and that for a variation of one minute the length of springs varies less than .004 of an inch.

If, however, an engine is racing, the speed of the anglemeter

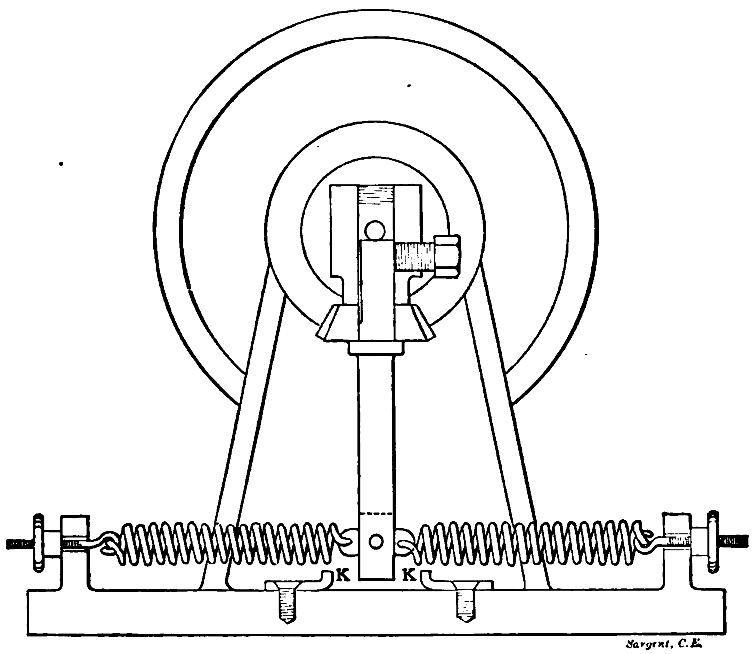


FIG. 165.

fly-wheel will rise and fall in proportion to that of the engine, for it makes in a minute some multiple of the engine speed.

The belt which is used to drive the anglemeter is a piece of special cotton tape one inch wide, butt-jointed with an ordinary over-cast stitch, which makes it practically endless; and as there is no perceptible stretch and but little inclination to creep, the speed of the light driving pulley of the anglemeter should vary exactly with the engine speed.

6. The amount of deflection of the needle each side of normal is readily seen when the anglemeter is in operation. When applied to a gas engine working under normal conditions, having two

impulses per revolution, as good results are obtained as from a single-crank steam-engine, but if abnormal conditions arise, such as premature or missed ignitions, the trouble is at once located by the needle's unusual deflections.

On account of the possible friction in tracing the movement of the needle point and the complicated mechanism of a moving chart, it has been thought best not to make the anglemeter recording, and it is therefore styled an indicating anglemeter.

Discussion.

Mr. Gus C. Henning.—I wish to object to the title of this paper. It should be goniometer, which is the common name for instruments used for measuring angles. I think our publication committee should modify this.

*Mr. Sargent.**—In reply to the objection raised by Mr. Henning to the use of the word anglemeter and his suggestion of the substitution of the term goniometer, I would say that the dictionary describes the latter as an instrument for measuring solid angles, or the inclination of planes, particularly the angles formed by the faces of crystals. It is therefore hardly applicable to the instrument in question which measures angular variation, and I believe that the term which I have chosen is the best.

* Author's Closure, under the Rules.

No. 987.*

THE STEAM TURBINE FROM AN OPERATING STAND-POINT.†

A DESCRIPTION AND TEST OF A 400 KW. TURBO-GENERATOR.

BY FREDK. A. WALDRON, STAMFORD, CONN.
(Member of the Society.)

1. THE steam turbine which this paper will describe is installed at the works of the Yale & Towne Manufacturing Co., Stamford, Conn., and is the first one of its size (outside of those operated by the builders) to be put into practical operation in this country. It is the writer's intention, therefore, to give not only an account of its installation and operation, but also data from the boiler room to a brake horse-power delivered from the driving pulley of the motor.

After a thorough investigation by the writer, in the early part of 1901, it was decided to install a Westinghouse-Parsons steam turbine for the following reasons:

(1) Floor space.

(2) Economy.

(3) Continuous operation of existing plant during installation of the new. (See Fig. 166, Power House, Building No. 13.)

The Problem was, Therefore, to Concentrate the Largest Amount of Power in the Smallest Possible Area Consistent with Economical Operation.

2. The generating outfit consists of a two-phase, 240-volt alternator, of 400 kilowatts capacity (when the turbine was run-

---

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions.*

† For further discussion on this topic, consult *Transactions* as follows:—
No. 845, vol. x., p. 680 : "Notes on Steam Turbine." J. B. Webb.
No. 648, vol. xvii., p. 81 : "Steam Turbine." W. F. M. Goss.
No. 876, vol. xxii., p. 170 : "Steam Turbines." R. H. Thurston.

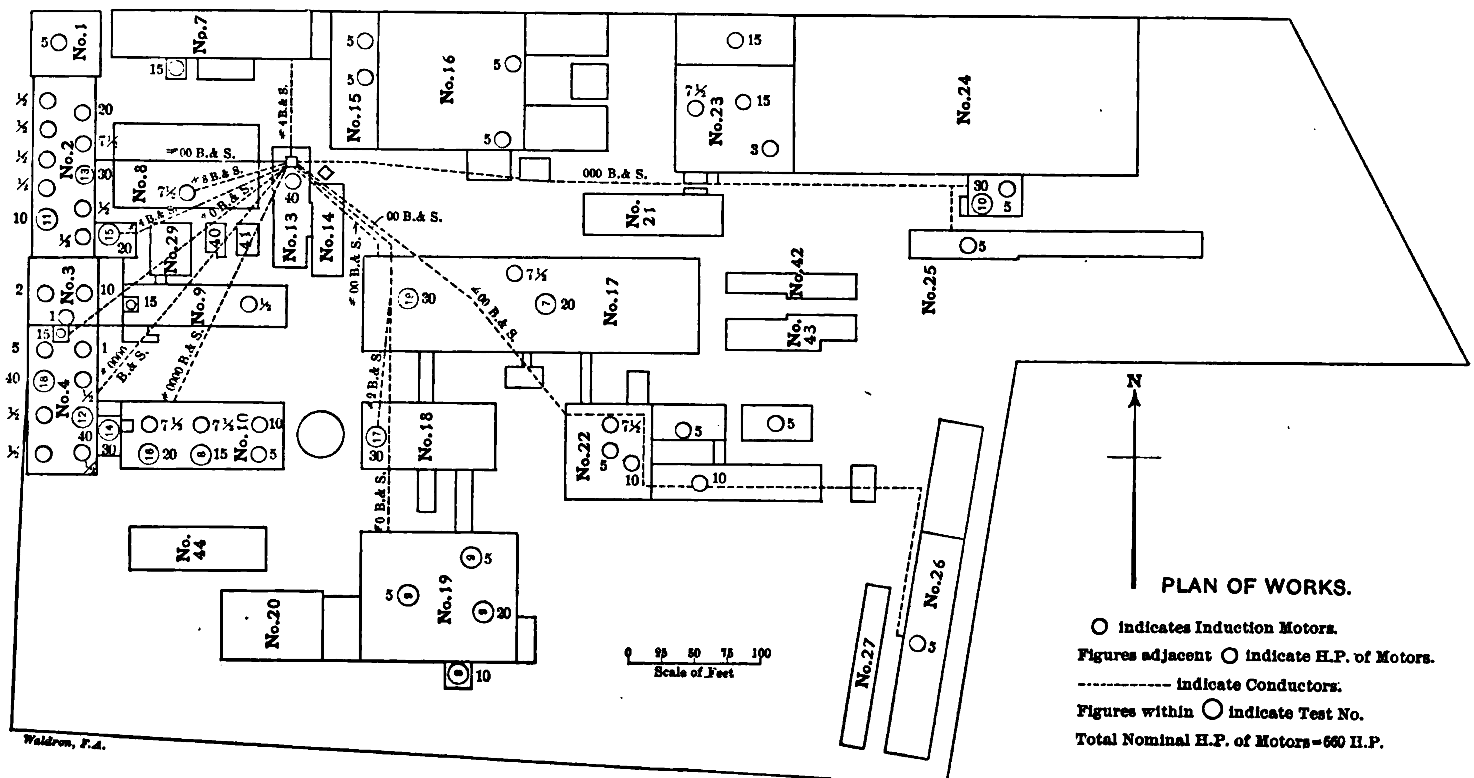

PLAN OF WORKS.
○ indicates Induction Motors.
Figures adjacent ○ indicate H.P. of Motors.
------------ indicate Conductors.
Figures within ○ indicate Test No.
Total Nominal H.P. of Motors=660 H.P.
Scale of Feet
N
Waldron, F.A.

FIG. 166.

ning condensing, and the power factor of the alternator was from 90 to 100 per cent.), 7,200 alternations, running at 3,600 revolutions per minute, with a separate, direct-connected exciter set. The alternator is of the revolving field type, and the surface speed of the field is 22,137 feet per minute. The weight of the outfit is 33,200 pounds, and occupies a floor space 19 feet by 4½ feet. (See Fig. 170.) The guaranteed economy was 16½ pounds of water per electrical horse-power at the switchboard, with 28 inches of vacuum, 40 degrees Fahr. superheat, and 155 pounds gauge pressure. Tests for economy, under slightly different conditions, reported later in this paper, will show how nearly the guarantee was reached. This opens the question of what is the average ratio between an indicated horse-power at the engine and an electrical horse-power at the switchboard.

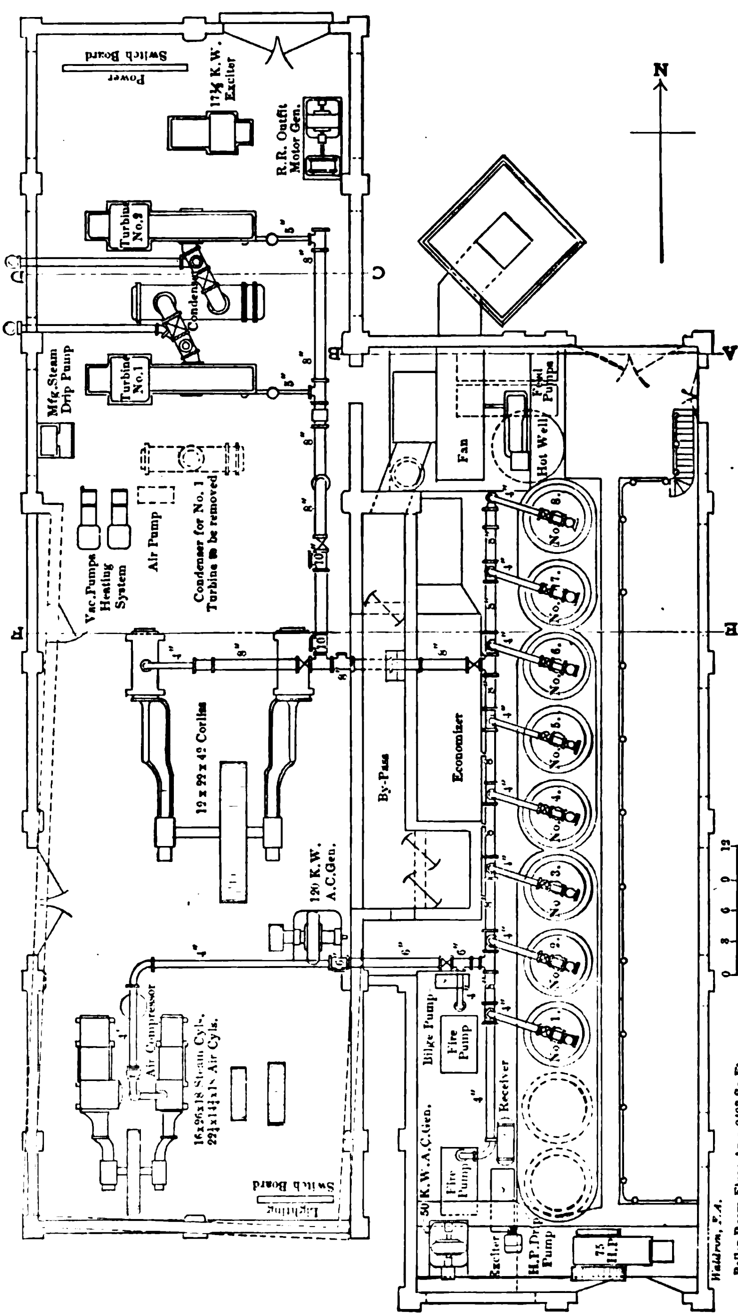
The electrical end of the machine is not compounded, and the variation in voltage depends entirely, within certain limits, upon the load and position of rheostats. Speed regulation is very close and perfectly satisfactory. A true kilowatt overload of 33⅓ per cent. has been carried for five consecutive hours, without apparent injury to the machine. Owing to the low power factor, however, the heat developed in the field and terminals was much higher than is allowable in good practice. When thus overloaded, the volt meter had to be closely watched, in order to care for any suddenly applied load with the rheostat.

3. At present, the condenser plant consists of a surface condenser, containing 1,100 square feet of cooling surface, with independent air and circulating pumps. The air-pump is of the simplex, twin beam, vertical type, making about 90 single strokes per minute. The average vacuum obtained with this outfit, with plenty of circulating water, is about 27.4 inches. This outfit is to be replaced by one of more recent design, and operated on the "Dry System" and with a two-stage vacuum pump.

4. Steam is furnished by eight Manning boilers, which are described in the Boiler Test. The general arrangement of Boiler and Power House, with its auxiliaries, is shown in Figs. 167, 168, 169 and 170.

It is not the author's intention to have the details of the steam generating plant form a portion of this paper, but he would be glad to give information to those who may wish it.

5. *Motors.*—Sixty-four (64) induction motors (with varying loads), ranging from ½ to 40 horse-power, are distributed



PLAN OF BOILER AND POWER HOUSE.

FIG. 167.

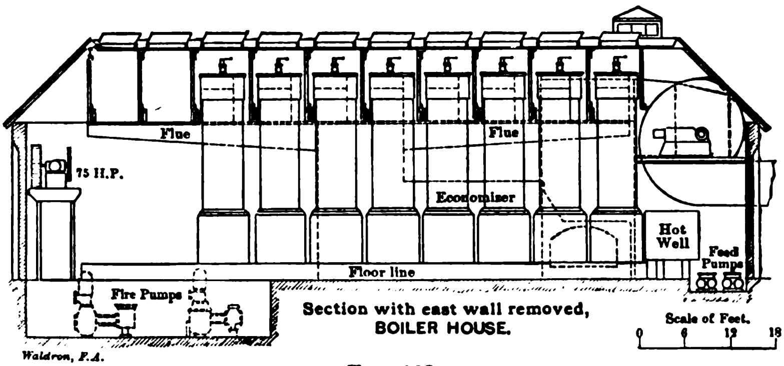


FIG. 168.

throughout the works. (See Fig. 166.) With the exception of the elevator motors, the entire plant is arranged on the group system. Wherever one or more machines are to be driven, belt-

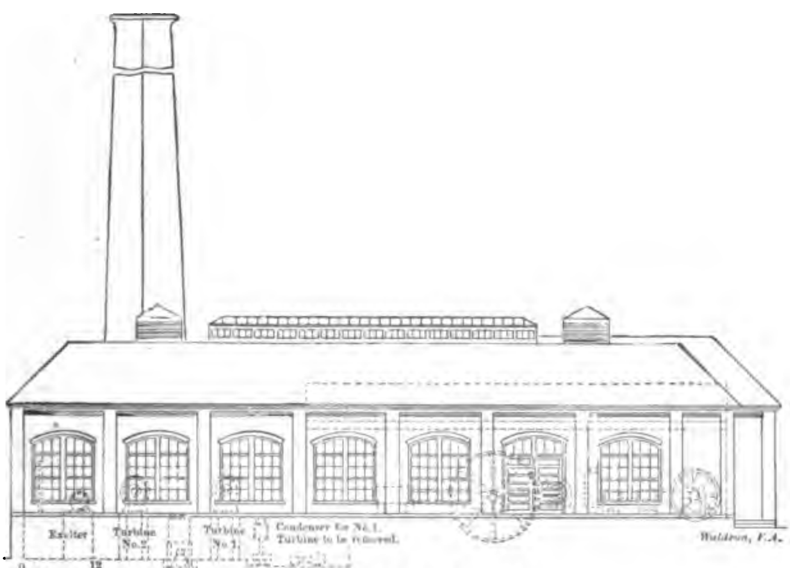
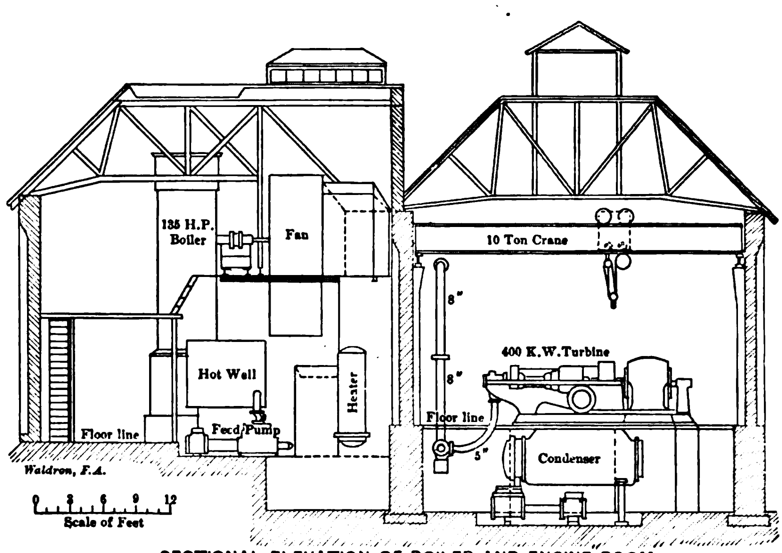


FIG. 169.

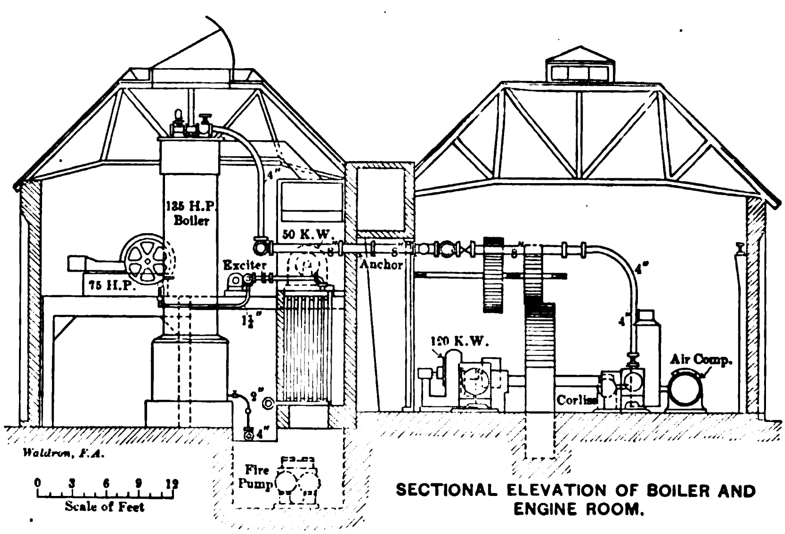
ing or gearing is used, and, if room will permit, belting is given the preference, for the following reasons:

(*a*) Flexibility.

(*b*) Less wear and tear on the motors.



SECTIONAL ELEVATION OF BOILER AND ENGINE ROOM.



SECTIONAL ELEVATION OF BOILER AND ENGINE ROOM.

FIG. 170.

(*c*) Absolute independence of speed of line shafts.

(*d*) Convenience in case of repairs.

(*e*) The advantage of changing, in event of increase or decrease of power requirements.

(*f*) Equal, if not higher, efficiency under continuous working conditions.

With this arrangement, the power factor will range from 82 to 86 per cent., depending on the motor loads. The only pre caution to take, in order to prevent frequent shut-downs, with the induction motor, is to have the main circuits fused heavy enough to withstand the influx of current to the line, due to starting. By referring to Fig. 166, the adaptability of electric transmission to a plant of this character is readily shown, without further explanation. There are, however, a number of conditions governing the installation that cannot be shown in the plans, a few of which are as follows:

6. The Iron Foundry (Building No. 24) which is situated about 700 feet from the Power House, requires, from 7 A.M. until 12 M., an average of about 7 horse-power, and from 3 to 5.15 P.M., about 35 horse-power.

Building No. 23 (which is an auxiliary to the Iron Foundry) requires from 25 to 30 horse-power to drive the tumbling barrels and grinders. When the blast is turned on to the cupola, in the afternoon, this motor is shut off, as the help are used in the foundry.

Building No. 25 requires 5 horse-power about one-half the time.

Box Shop (Building No. 26) is situated about 1,000 feet from the Power House, the nearest line shaft being about 300 feet away from it. A 5 horse-power motor is used for about three hours a day, at this point.

The Plating Room, fifth floor (Building No. 4) uses from 45 to 50 horse-power, five hours per day, and 8 to 10 horse-power for the remaining five hours.

7. Owing to manufacturing requirements, it is found necessary to run the shafting both lengthwise and crosswise with the building. For example, Buildings Nos. 1, 2, 4 and 10 have shafting running in both directions. The electric system of transmission lends itself admirably to this condition. Had this factory been one continuous building of from two to four stories high, with the Power House centrally located, shafting running in one direction, and light machinery installed along its line continuously, the question of the economy of electric transmission would have been doubtful. Tests described farther on, and Tests Nos. 7 to 19 inclusive, will furnish complete data as to the economy of electric transmission, as applied to this particular case. (See page 1030).

8. *The Turbine and Its Generator.*—The turbine end of this machine has received very little attention in the past year, and has required no renewals or repairs to any of its parts; in fact, from an operating standpoint, it is almost fool-proof. It was found necessary, when assembling the machine, over a year ago, to remove from the bearings, with a fine oil-stone, some burrs which had been thrown up in handling, and also a little rust which had accumulated; upon examination of the same, one year later, these marks had not been worn out, and there was absolutely no difference in the recorded diameters of the bearings, covering a period of one year's wear.

Occasional longitudinal adjustment, to check the clearance between the blades in the case and the revolving element, is necessary. The wear and tear on other parts of the machine have been practically nil, and if the oil is kept in constant circulation and properly cooled, there is no need of a "hot box," and the amount of oil used is extremely small; the consumption of this particular machine being ½ gallon of cylinder oil per week, and from 3 to 5 per cent. of the lubricating oil on the bearings may be said to be wasted. The quality of the oil used should be perfectly free from acids which would, in any way, tend to injure the bearings. Considerable apprehension has been felt by a great many who have not come in actual contact with the turbine that the blades in the revolving element would be a source of trouble. If the machine is properly set and adjusted, with a chance for expansion between the machine and its condenser, there is (outside of defective material) absolutely no danger from these blades. It is necessary to remove the top of the case of the turbine once in three months (especially when the plant is first started), as red lead or other foreign substances in the pipes are liable to clog the smaller blades, although a steam strainer is provided, which cares for any foreign substances which may in any way injure them.

9. The principal trouble with the steam end is its liability to shut down, when running from ¾ to full load, if the vacuum is destroyed. This can be prevented, if the engineer is on hand, but sometimes he isn't there, and we have had one or two shut-downs, in the last year, from this cause. I am informed, however, that a device for automatically preventing this is being designed by the makers, and we expect to have it on our second machine.

It is desirable to place in the pipe for cooling water for the oil well an eel-trap with a by-pass, and, what is still better, if convenient, to have two sources of water supply. An open drip should also be provided, which can be frequently tried by the engineer, to insure proper circulation of cooling water. The electrical end of the machine has given us *all* the trouble—not from the result of electrical design and defect, but from mechanical defects, pure and simple.

10. The field or revolving element is made of four cylindrical forgings, 23⅝ inches in diameter, aggregating in length about 28 inches. These sections are forced on to the shaft, with about 150 tons pressure. Owing to centrifugal force and the heat developed in the field, one of these sections crept on the shaft about ⅜ of an inch, the result being that, on the 21st of August, 1902, one of the field wires was pulled apart. Repairs were quickly made and the makers agreed to furnish a new field, which was placed in position the latter part of December; when, upon starting the machine for the purpose of testing, it immediately (upon attaining full speed, and without any load upon it) flew into a large number of pieces, entirely demolishing the electrical end, and badly damaging the steam end. Investigation showed that invisible flaws in the forging were the cause of this accident. No damage was done to the building, outside of the breaking of a few panes of glass, neither were any of the occupants injured, although there were eight men in the room at the time.

From the various accounts of fly-wheel accidents, I think that the majority of the members, after observing the photographs which the writer will exhibit to those who desire to look at them, will admit that, in spite of its high speed, the field of devastation is not so great in the case of the turbine as the reciprocating engine.

11. A memorandum has been kept by the author of all of the questions which have been asked him in regard to this installation, and, as a matter of record, he would like to place the more important ones before the Society, in the order of their importance:

(1) Does it fulfill the guaranteed economy?

In answer to this see Tests Nos. 2, 3, 4 and 5.

(2) Is the windage excessive?

It certainly is more than from a slow speed generator, yet, as a whole, is not disagreeable, as noise in the engine room is a comparative quantity.

(3) Are you satisfied with the continuity of operation?

Outside of the breakdown (which was due to defective material, or to causes entirely foreign to the machine), it is entirely satisfactory.

(4) What condensing outfit is necessary?

This is a question which each purchaser can best decide for himself. The writer's experience, however, is that the best is none too good, and that for continuous running and high vacuums, the dry system, with a two-stage air-pump, will probably maintain higher average vacuums than any other system.

(5) Can exhaust steam be used for heating?

This turbine has supplied 25,000 square feet of direct radiating surface and 7,500 square feet of blower-stack surface, and maintained a temperature of from 60 to 70 degrees Fahr. in all buildings, when generating 520 kilowatts, and with a temperature of 220 degrees Fahr. in the exhaust chamber of the turbine. The differential in pressure was produced by 10 inches of vacuum on the Power House end of the drips for the heating system. The writer has also found that the temperature in the exhaust chamber of the turbine varies with the different loads, and at full load and overload, there is more or less superheat, whether running condensing or non-condensing.

(6) What overload will it stand?

A 50 per cent. overload has been maintained at full speed, for five hours, without apparent injury to the machine.

(7) Can it be changed from condensing to non-condensing, and *vice versa*, when running?

This we have done daily, during the heating period, and without difficulty or shut-down, according to the following schedule:

Non-condensing, 7 A.M. to 10 A.M.; 1 P.M. to 3 P.M.
Condensing, 10 A.M. to 12 M.; 3 P.M. to 6 P.M.

(8) Type of exciter?

The exciter should be driven by an independent engine.

(9) Is your confidence in the machine shaken, after the trouble you have had with it?

The best reply to this is that a second outfit has been ordered.

(10) Cost?

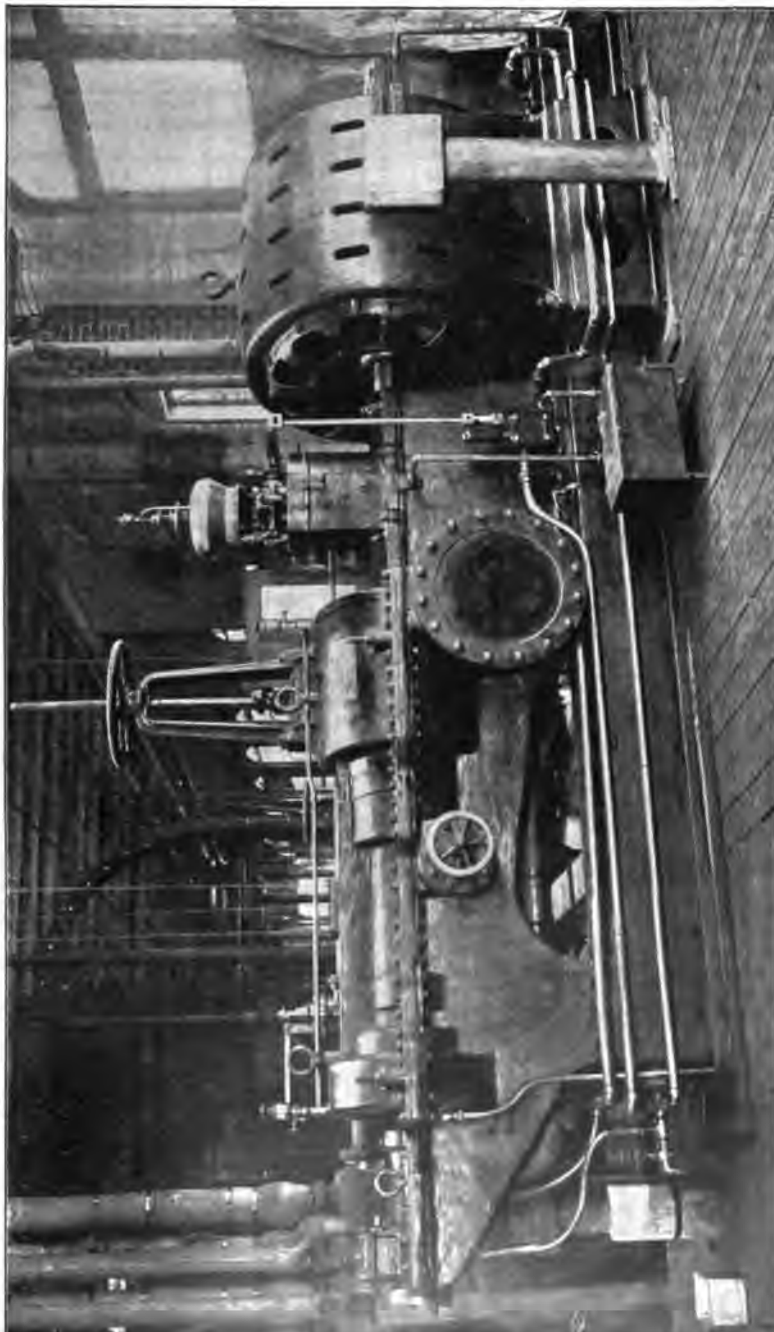


Fig. 171.

Upon the basis of strictly competitive prices, the turbine, ready to run, costs from 10 to 15 per cent. less than the same sized reciprocating engine outfit.

The cost of the Power House, per square foot, per kilowatt, would be about 35 per cent. less for a turbo-generator outfit than for a reciprocating engine of the same power and economy. The cost of foundations is taken into account, in the cost of the engine and turbine. The cost of piping is not included in either case, excepting the piping between the throttle and the condenser.

(11) Is the vibration excessive?

The author considers that, unless it is possible to balance a lead pencil on the outboard bearing and allow it to remain there for a minute, the machine is vibrating more than it should; and while there are no foundation bolts to hold the machine down, there has been no tendency for it to creep on its foundations.

12. It has been before the author's mind in presenting the results of these tests that readers might obtain information on the following questions:

(1) *Cost.*—(*a*) Cost of turbo-generator; (*b*) cost of land and buildings.

(2) *Economy.*—(*a*) Coal consumption; (*b*) oil; (*c*) repairs; (*d*) constant economical condition, which is commercially inherent in construction of machine; (*e*) return of condenser discharge to boiler.

(3) *Ease of Operation.*—(*a*) Accessibility; (*b*) starting and stopping; (*c*) oiling and adjustment; (*d*) running in parallel.

(4) *Compactness.*

13. The illustrations accompanying this paper are as follows:

Fig. 166 is a general plan of the works. The circuits are indicated by broken lines, also their sizes in numbers of Brown & Sharpe gauge. The size and location of motors are shown by small circles, and their horse-power is indicated by small figures, adjacent to circles. The numbers of the buildings are also placed upon them, and are referred to at different times, in the paper. The figures inside of circles refer to the motor-test number given in the tabulation of motor tests. (See page 1030).

Fig. 167 is a plan of the Boiler and Power House.

The two turbines are shown in place, with their condenser connections. Turbine No. 1 is the subject of this paper. Turbine No. 2 is in course of construction.

The exciter outfit is shown to the right of Turbine No. 2, and is of sufficient capacity to care for both turbines. By removing the switch-board to a gallery (which can be readily constructed), another turbine could be easily placed in this room. It may be interesting to know that the foundation of Turbine No. 1 cost $188.60, at the current prices of cement, sand and broken stone, in 1901–2. It is advisable to leave the foundations with a tunnel through the centre, transversely, as there are many ways in which these tunnels can be utilized, either for piping or ducts for electrical wiring.

Fig. 168 is a longitudinal elevation and section of Boiler House.

Fig. 169 is a longitudinal elevation of Power House. A 350 horse-power cross-compound engine, and a 150 horse-power air compressor are shown to the right, with the two turbines and accessories at the left.

Fig. 170 is a sectional elevation of Power and Boiler Houses, and sections are taken on lettered lines of Fig. 167.

14. With respect to the boiler tests it should be said that they were made under daily running conditions, without attempt to scrape the tubes of the boilers, or to bring the economy to a phenomenally high point. What is known as the Society's Alternate Method is used, since at this time of year it is difficult to draw the fires and re-start them. The calorific power of the coal was 13,338. The usual precautions as to calibration of gauges, leakage from pumps and the like were observed.

Concerning the tests of the turbine, the same conditions prevailed. No special attempt was made to obtain an unusual vacuum.

The condenser was tested for leakage, and all water was measured from the air-pump discharge. The power for the exciter (10.8 kilowatts) was determined in a separate test. The exhaust from the exciter engine is used for heating purposes. Shop tests on the turbine made eighteen months before the test in this paper, showed an economy of 14.47 pounds of water per brake horse-power with a load of 607 brake horse-power and 16.43 pounds of water per brake horse-power, with a load of 263 brake horse-power (200 kilowatts). These tests were under approximately the same conditions as to pressure, vacuum and superheat as those in this paper.

15. The tests on motors are intended to present detailed losses of power transmission, as applied to the group system, with

different arrangements of line shafting and belting, as well as different applications of the electric motor to factory work.

The diagrams accompanying each test show that, in all cases, the motor is belted to the shafting, or to jack-shafting, or to the machine which it is intended to drive.

The principal points brought out by the tests are:

(*a*) Difference in frictional losses, depending on speed and arrangements of shafting in the different rooms.

(*b*) The power utilized by the machinery, when running idle.

(*c*) The total power used by the shafting, machinery and useful work.

(*d*) Efficiency of electric transmission.

16. The tests were made under actual running conditions; the test for each room being continued for one half day, with regular working load, and readings of the watt meter were taken every two minutes. The mean vibration of the pointer was taken as the true reading. The efficiency of the motors (under their different loads) was taken from the curves furnished by the builders.

The analysis of these tests would indicate that, with the turbo-generator driving induction motors, and with an evaporation of 8.707 pounds of water, per pound of coal, a brake horse-power can be delivered from the pulley of the motor for about 2½ pounds of coal (see table of tabulation of motor tests 7 to 19 inclusive), with a turbine of this size running under average economy. (This allows 5 per cent. for banking.)

Under the same evaporative conditions, the average non-condensing engines, distributed through the different rooms in the plant, would require 7.5 pounds of coal per brake horse-power at the fly-wheel, or three times that quantity required for the electrical drive.

As to what would be the actual saving under the existing conditions at this factory, over belt transmission, it would be impossible to calculate, as the conditions which exist at the present are so entirely different from former conditions, owing to the rapid growth of the plant.

17. What the loss might have been between the engine and pulleys which deliver power to the different rooms, is an unknown quantity. Further, under the conditions which existed at that time, and do exist now, about one-half our steam is utilized for manufacturing purposes and for heating. The question,

therefore, of the comparative total cost of power, is a matter which must be arbitrarily determined, depending on the ratio of the Power House charges for power and manufacturing steam. As this is entirely arbitrary, it is not permissible to quote any figures as to the relative costs of power, under the two conditions, as they would be inaccurate and misleading to others.

One of the interesting questions answered by these tests is the small amount of power actually used in removing stock, in light manufacturing work.

18. In conclusion, the results obtained from this outfit may not be any higher than many obtained by direct connected sets of the same size, running under maximum economical conditions. Assuming, however, that they are the same, the advantages of initial investment, constant economy and the possible extension of the plant with the turbo-generator outfit, are of sufficient importance to warrant the installation.

The strongest appeal, however, that the turbo-generator makes to the business man or the engineer is its inherent commercial efficiency. By this, I mean that its efficiency is unchanged, week in and week out; year in and year out. Leaky pistons or valves, lack of alignment of slides and bearings, keying up, and, above all, lubrication, all of which exist in the reciprocating engine, are eliminated in the turbine.

The detail of the tests appear in the following :

BOILERS.

Eight Manning Boilers of 135 Horse-Power Each.

Dimensions of one boiler.

Grate surface	28.27 sq. ft.
Heating " 1388.42 sq.ft. Super-heating, 467.56 sq. ft.—Total,	1855.98 sq. ft.
Cal. area	5.11
Ratio of Cal. to G. S	1:5.53
" " G. S. to Water H. S	1:49.11
" " " " Super "	1:16.54
" " " " Total	1:65.65
Length of Tubes	14 ft., 11 ins.
Diam. " "	2¼ ins.
Number " "	180
Economizer	144 tubes, 4 in.—6 tubes wide.
H. S	1,728 sq. ft.
Induced draft,	
Size of Fan, dia. 9 ft.; width, 4 ft. 6 ins. Outlet, 62 × 54 ins. Inlet, 100 ins. × 46 ins.	
Size of Engine, 8 × 10 ins. Ave. No. R. P. M.	114.3

BOILER TESTS.

Test of Seven 135 Horse-Power Manning Boilers.

Test No. 1. *Method of Starting (Alternate).*

Grate surface	197.89 sq. ft.
Water-heating surface	9,718.94 sq. ft.
Superheating surface	3,272.92 sq. ft.

Total Quantities.

1. Date of trial	March 25, 1903.
2. Duration of trial, in hours	11
3. Weight of coal, as fired	30,681 lbs.
4. Percentage of moisture in coal	8 Per cent.
5. Total weight of dry coal consumed	28,226.52 lbs.
6. Total ash and refuse	2,835.00 "
7. Percentage of ash and refuse, with dry coal	10 per cent.
8. Total weight of water	267,150.0 lbs.
9. Water actually evaporated (corrected for superheat)	290,192.6 "
9a. Factor of evaporation	1.176
10. Equivalent water evaporated into dry steam, from and at 212 degrees	314,168.4 lbs.

Hourly Quantities.

11. Dry coal consumed per hour	2,566.04 lbs.
12. Dry coal per sq. ft. of grate surface per hour	12.97 "
13. Water evaporated per hr. (corrected for quality of steam).	25,472.05 "
14. Equivalent evaporation per hour, from and at 212 degrees	28,560.76 "
15. Equivalent evaporation per hr. from and at 212 degrees per sq. ft. of water heat. surface	2.938

Average Pressures, Temperatures, etc.

16. Steam pressure by gauge	151.00 lbs.
17. Temperature of feed-water entering boiler	148.07° Fahr.
18. Temperature of escaping gases from boiler.	469.20° "
19. Force of draft between damper and boiler	.23 inch.
20. Superheat (degrees)	21.08° Fahr.

Horse-power.

21. Horse-power developed	827.84
22. Rated horse-power	945.
23. Percentage of rated horse-power developed	87.6 per cent.

Economic Results.

24. Water apparently evaporated, per lb. of coal, (actual conditions)	8.707 lbs.
25. Equivalent evaporation from and at 212 degrees per pound of coal, as fired	10.240 "
26. Equivalent evaporation from and at 212 degrees per pound of dry coal	11.130 "
27. Equivalent evaporation from and at 212 degrees per pound of combustible	12.370 "

Efficiencies.

28. Calorific value of dry coal per pound	13,488 B.T.U.
29. Calorific value of combustible per pound	15,433 "

Cost of Evaporation.

30. Cost of coal per ton of 2,240 pounds delivered in Boiler Room	$3.5300
31. Cost of coal required for evaporation of 1,000 lbs. of water, from and at 212 degrees	0.1539

In reference to the matter of coal, the amount of refuse, as per calorimeter tests, was 12.6 per cent. Assuming this as the total ash, the evaporation per pound of combustible was equal to 12.69 pounds.

The percentage of moisture in the coal is considerably more than under ordinary conditions, as it was raining on the day before the test and the coal was not housed. A large number of samples, however, were taken and dried, in order to obtain this percentage.

The total heat of steam, at 21.08 superheat, was figured from Wood's formula, as follows:

$H = 1{,}091.7 + 0.48\ (T - 32 \text{ degrees})$ in which H = total heat units above 32 degrees; T = temperature of steam.

The factor of evaporation was then figured by the regular formula, as given in the Society's code for boiler tests.

(150 KILOWATT TEST.)

Economy Tests of 400 Kilowatt Turbo-Generator.

Test No. 2. Date, *April* 13, 1903.

Voltage	227.5
Average R. P. M	3,600
Maximum speed variation, as per tachometer	0.5 p. c.
Average load	152 K. W.
" water, per hour	4,263.3 lbs.

Duration of test	3 hrs.
Steam pressure (per gauge) at throttle	144.85 lbs.
Average vacuum	27.34 ins.
Water per K. W., per hour	28.05 lbs.
" " E. H. P. = $\frac{\text{Water per K. W. hour} \times 746}{1{,}000}$	20.92 "
" " B. H. P = Gen. Eff. (0.91) × Water per E. H. P. per hour	19.03 "
Water per I.H P. = Water per E. H. P. per hr. × 0.85	17.78 "
Maximum average load for 1 hour	152 K. W.
Minimum " " " "	152 "
Maximum water rate per K. W. hour	28.27 lbs.
Minimum " " " "	27.91 "
Maximum vacuum	27.42 ins.

K. W. = Kilowatts.
E. H. P. = Electric Horse-power.
B. H. P. = Brake Horse-power.
I. H. P. = Indicated Horse-power.

This test was made after working hours, with the boiler running very light, which accounts for the low pressure, and lack of superheat.

(300 KILOWATTS TEST.)

ECONOMY TESTS OF 400 KILOWATT TURBO-GENERATOR.

TEST No. 3. DATE, *April* 14, 1903.

Voltage	227.5
Average R. P. M	3,600
Maximum speed variation, as per tachometer	0.5 p. c.
Average load	323 K. W.
" water, per hour	7,217.3 lbs.
Duration of test	3 hrs.
Steam pressure (per gauge) at throttle	153.3 lbs.
Superheat at throttle " "	3.44° Fahr.
Average vacuum	27.64 ins.
Water per K. W., per hour	22.34 lbs.
" per E. H. P. = $\frac{\text{Water per K. W. hour} \times 746}{1{,}000}$	16.67 "
Water " B. H. P. = Gen. Eff. (0.91) × Water per E. H. P. per hour	15.17 "
Water per I. H. P. = Water per E. H. P. per hr. × 0.85	14.17 "
Maximum average load for 1 hour	323 K. W.
Minimum " " " "	323 "
Maximum superheat	9.97° Fahr.
" water rate per K. W. hour	22.70 lbs.
Minimum " " " "	22.03 "
Maximum vacuum	27.71 ins.

(RUNNING LOAD.)

ECONOMY TESTS OF 400 KILOWATT TURBO-GENERATOR.

TEST No. 4. DATE, *April* 17, 1903.

Voltage	227.5
Average R. P. M	3,600
Maximum speed variation, as per tachometre	0.5 p. c.
Average load	375 K. W.
" water, per hour	8,358.5 lbs.
Duration of test	4 hrs.
Steam pressure (per gauge) at throttle	152 lbs.
Superheat at throttle " "	6.46° Fahr.
Average vacuum	27.43 ins.
Water per K. W., per hour	22.29 lbs.
Water " E. H. P. = $\frac{\text{Water per K. W. hour} \times 746}{1,000}$	16.63 "
Water " B. H. P. = Gen. Eff. (0.91) × Water per E. H. P., per hour	15.13 "
Water per I. H. P. = Water per E. H. P., per hr. × 0.85	14.13 "
Maximum average load for 1 hour	383 K. W.
Minimum " " " "	367 K. W.
Maximum superheat	18.27° Fahr.
" water rate per K. W. hour	23.11
Minimum " " " "	21.46
Maximum vacuum	27.84 ins.

(400 K. W. TEST.)

ECONOMY TESTS OF 400 KILOWATT TURBO-GENERATOR.

TEST No. 5. DATE, *April* 17, 1903.

Voltage	227.5
Average R. P. M	3,600
Maximum speed variation, as per tachometer	0.5 p. c.
Average load	397.11 K. W.
" water, per hour	8,798.66 lbs.
Duration of test	3 hrs.
Steam pressure per gauge, at throttle	150.92 lbs.
Superheat at throttle	19.66° Fahr.
Average vacuum	26.95 ins.
Water per K. W., per hour	22.156 lbs.
" " E. H. P. = $\frac{\text{Water per K. W. hour} \times 746}{1,000}$	16.53 "
" " B. H. P. = Gen. Eff. (0.91) × Water per E. H. P., per hour	15.04 "
Water per I. H. P. = Water per E. H. P., per hour × 0.85	14.05 "

Maximum average load for 1 hour..	398.26 K. W.
Minimum " " " "	394.92 K. W.
Maximum superheat	24.27° Fahr.
" water rate per K. W. hour	22.45 lbs.
Minimum " " " "	22.18 "
Maximum vacuum	27.85 ins.

OVERLOAD TEST.

Economy Tests of 400 Kilowatt Turbo-Generator.

Test No. 6. Date, *Dec.* 11, 1902.

Voltage	238.70
Average R. P. M	3,600
Maximum speed variation as per tachometer	0.5 p. c.
Average load	490 K. W.
" water per hour	10,625.8 lbs.
Duration of test	5 hrs.
Steam pressure per gauge, at throttle	152.7 lbs.
Superheat at throttle	18.2° Fahr.
Average vacuum	27.55 ins.
Water per K. W., per hour	21.7 lbs.
" " E. H. P. = $\frac{\text{Water per K. W. hour} \times 746}{1{,}000}$	16.18 "
" " B. H. P. = Gen. Eff. (0.91) × water per E. H. P. per hour	14 72 "
Water per I. H. P. = Water per E. H. P. per hr. × .085 ..	13.75 "
Maximum average load for 1 hour	525. K. W.
Minimum " " " "	432. "
Maximum superheat	26.6° Fahr.
" water rate per K. W. hour	22.33 lbs.
Minimum " " " "	21.22 "
Maximum vacuum	27.65 ins.

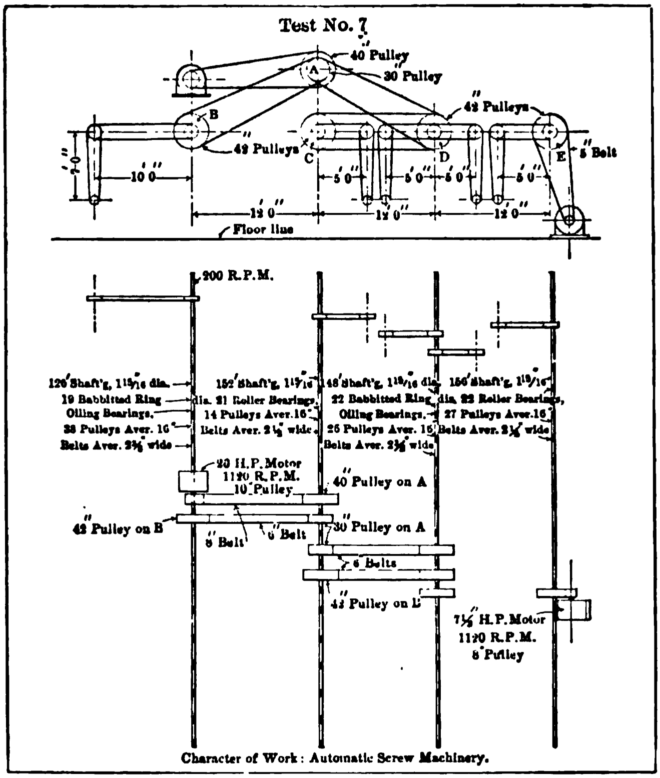

Test No. 7
40" Pulley
30" Pulley
42" Pulleys
A
B
C
D
E
42" Pulleys
5" Belt
2' 0"
10' 0"
5' 0"
5' 0"
5' 0"
5' 0"
12' 0"
12' 0"
12' 0"
Floor line
200 R.P.M.
120' Shaft'g, 1 15/16" dia.
19 Babbitted Ring
Oiling Bearings.
38 Pulleys Aver. 16"
Belts Aver. 2⅝" wide
152' Shaft'g, 1 17/16" dia.
21 Roller Bearings.
14 Pulleys Aver. 16"
Belts Aver. 2½" wide
148' Shaft'g, 1 15/16" dia.
22 Babbitted Ring
Oiling Bearings.
26 Pulleys Aver. 16"
Belts Aver. 2⅝" wide
156' Shaft'g, 1 15/16" dia.
22 Roller Bearings,
27 Pulleys Aver. 16"
Belts Aver. 2½" wide
20 H.P. Motor
1120 R.P.M.
10" Pulley
40" Pulley on A
42" Pulley on B
6" Belt
6" Belt
30" Pulley on A
6" Belts
42" Pulley on D
7½" H.P. Motor
1120 R.P.M.
8" Pulley
Character of Work: Automatic Screw Machinery.

FIG. 172.

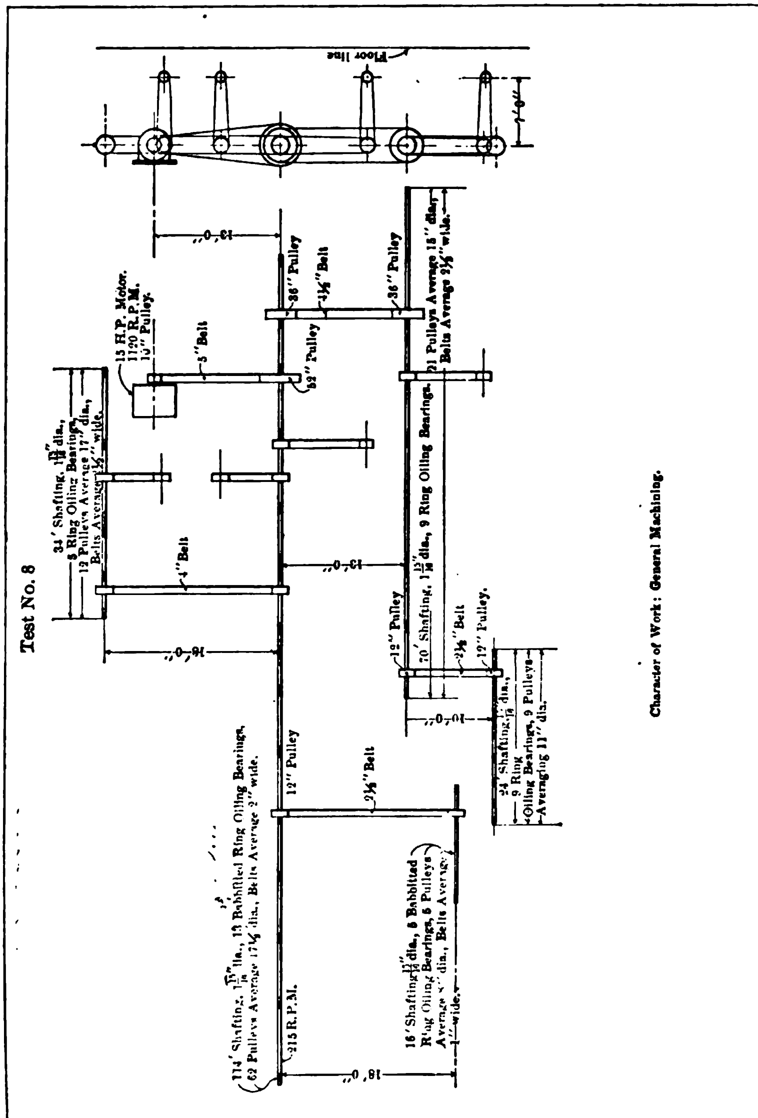

Test No. 8
Floor line
15 H.P. Motor. 1120 R.P.M. 10" Pulley.
5" Belt
4" Belt
36" Pulley
4½" Belt
32" Pulley
12" Pulley
2½" Belt
215 R.P.M.
Character of Work: General Machining.

FIG. 173.

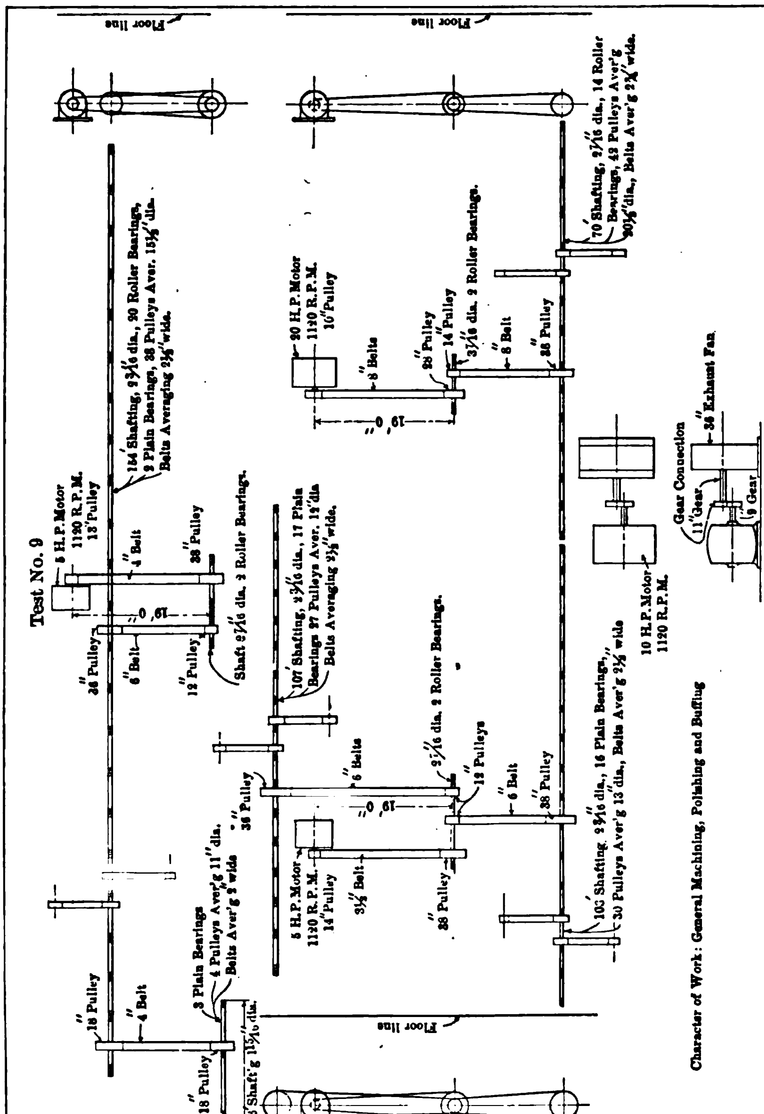

Test No. 9
Character of Work: General Machining, Polishing and Buffing

FIG. 174.

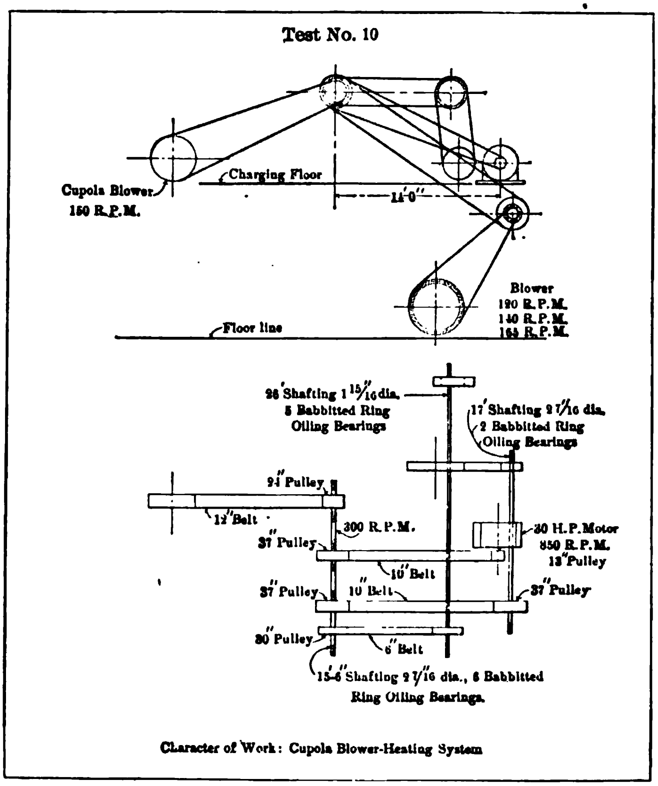

Test No. 10
Cupola Blower
150 R.P.M.
Charging Floor
14'-0"
Blower
120 R.P.M.
140 R.P.M.
165 R.P.M.
Floor line
26' Shafting 1 15/16" dia.
5 Babbitted Ring
Oiling Bearings
17' Shafting 2 7/16 dia.
2 Babbitted Ring
Oiling Bearings
9½" Pulley
12" Belt
300 R.P.M.
37" Pulley
30 H.P. Motor
850 R.P.M.
13" Pulley
10" Belt
37" Pulley
10" Belt
37" Pulley
30" Pulley
6" Belt
15'-6" Shafting 2 7/16 dia., 6 Babbitted
Ring Oiling Bearings.
Character of Work: Cupola Blower-Heating System

Fig. 175.

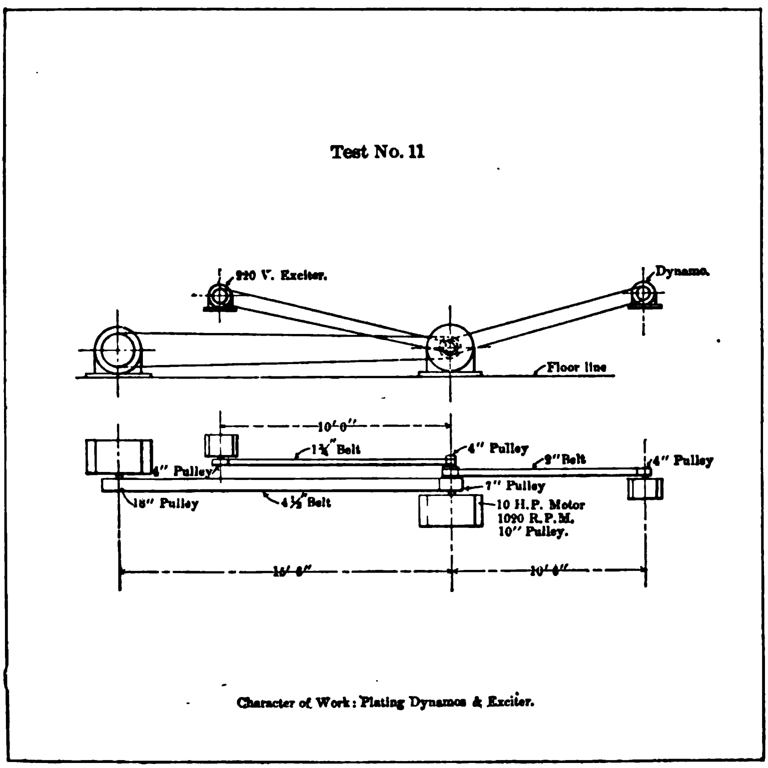

Test No. 11
220 V. Exciter.
Dynamo.
Floor line
10' 0"
1¼" Belt
4" Pulley
2" Belt
4" Pulley
4" Pulley
7" Pulley
18" Pulley
4½" Belt
10 H.P. Motor
1020 R.P.M.
10" Pulley.
Character of Work: Plating Dynamos & Exciter.

FIG. 176.

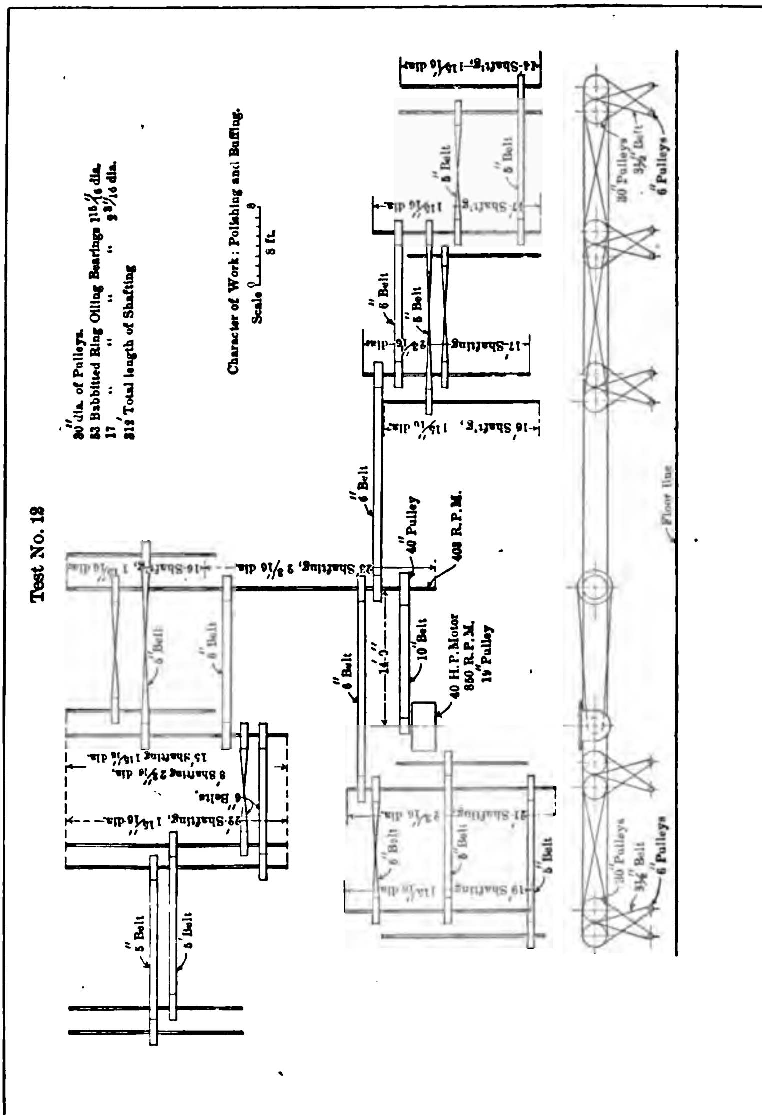

Test No. 12
30" dia. of Pulleys.
53 Babbitted Ring Oiling Bearings 1 15/16" dia.
17 " " " 2 3/16 dia.
312' Total length of Shafting
Character of Work: Polishing and Buffing.
Scale 8 ft.
40" Pulley
403 R.P.M.
40 H.P. Motor
850 R.P.M.
19" Pulley
10" Belt
6" Belt
14'-0"
Floor line
30" Pulleys
3½" Belt
6" Pulleys

FIG. 177.

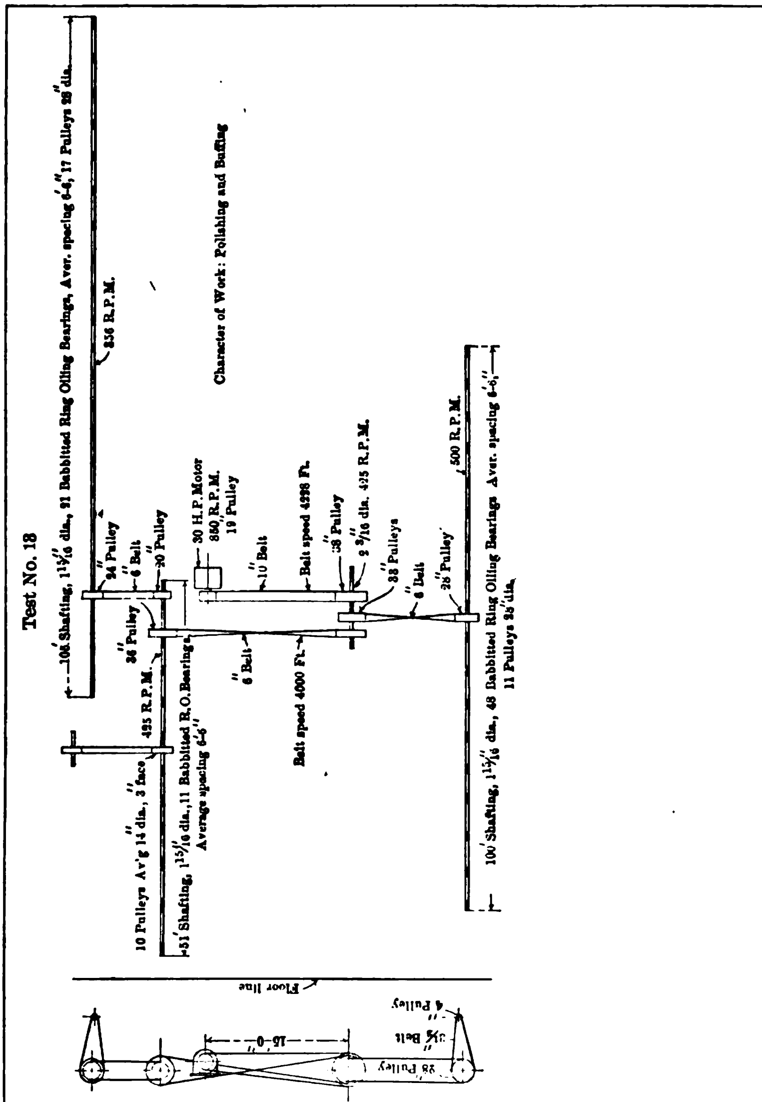

Test No. 18
108' Shafting, 1 15/16" dia., 21 Babbitted Ring Oiling Bearings, Aver. spacing 6'-6", 17 Pulleys 23" dia.
236 R.P.M.
Character of Work: Polishing and Buffing
24" Pulley
6" Belt
30" Pulley
36" Pulley
425 R.P.M.
30 H.P. Motor
850 R.P.M.
19" Pulley
10" Belt
Belt speed 4228 Ft.
38" Pulley
2 3/16" dia. 425 R.P.M.
38" Pulleys
6" Belt
28" Pulley
500 R.P.M.
6" Belt
Belt speed 4000 Ft.
100' Shafting, 1 15/16" dia., 48 Babbitted Ring Oiling Bearings Aver. spacing 6'-6"
11 Pulleys 23" dia.
10 Pulleys Av'g 14" dia., 3" face
51' Shafting, 1 15/16" dia., 11 Babbitted R.O. Bearings, Average spacing 6'-6"
Floor line
15'-0"
4" Pulley
3½" Belt
28" Pulley

FIG. 178.

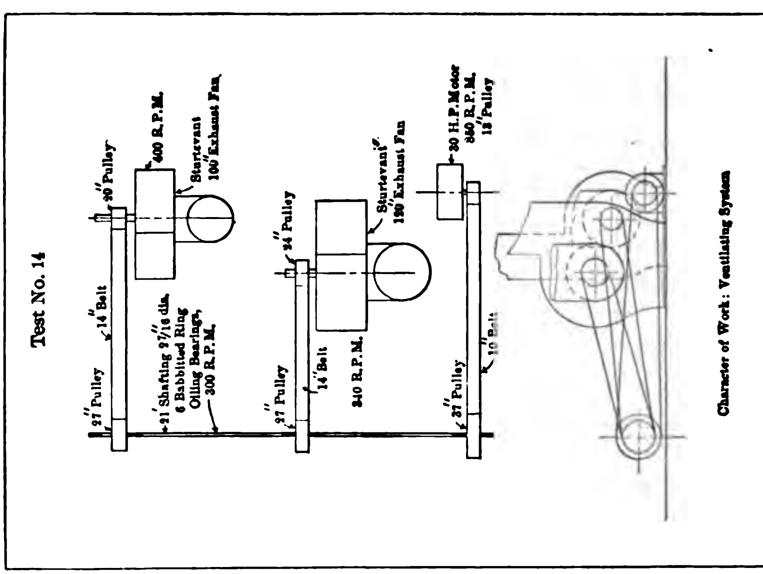


FIG. 179.

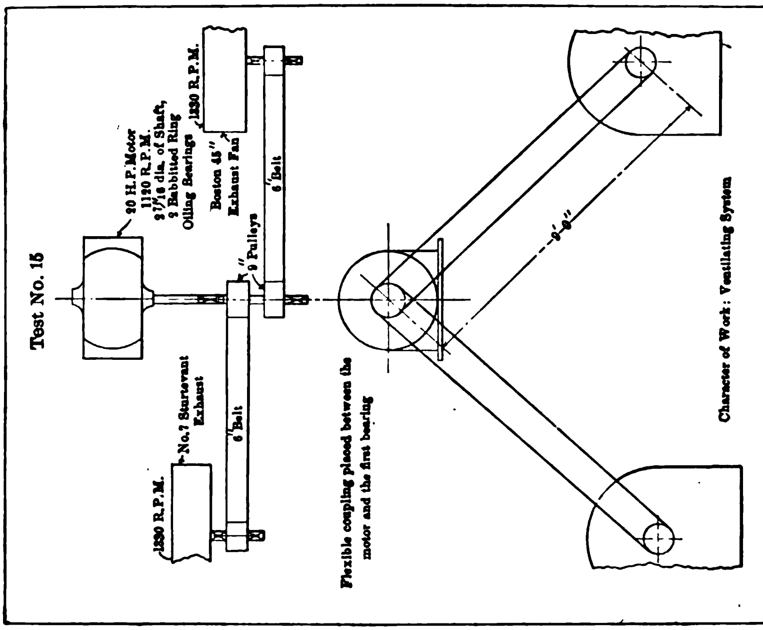


FIG. 180.

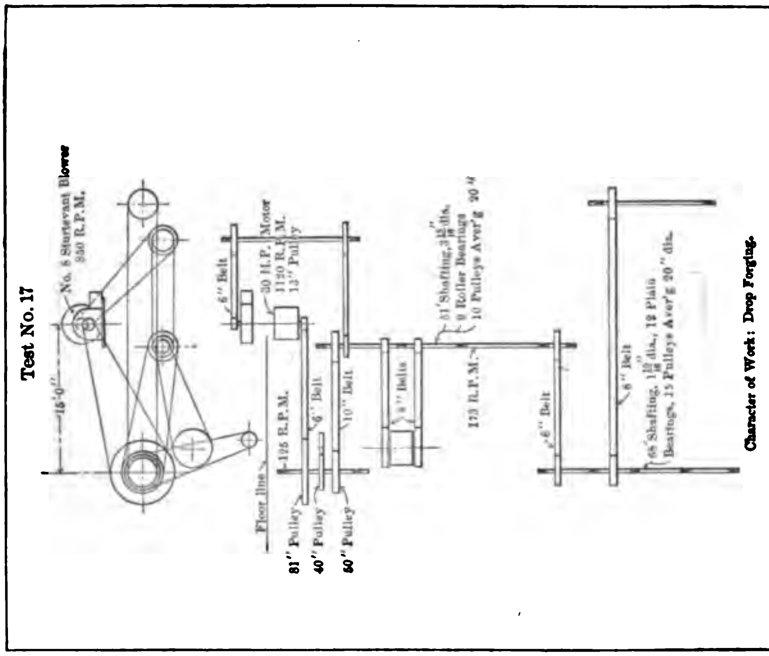


FIG. 182.

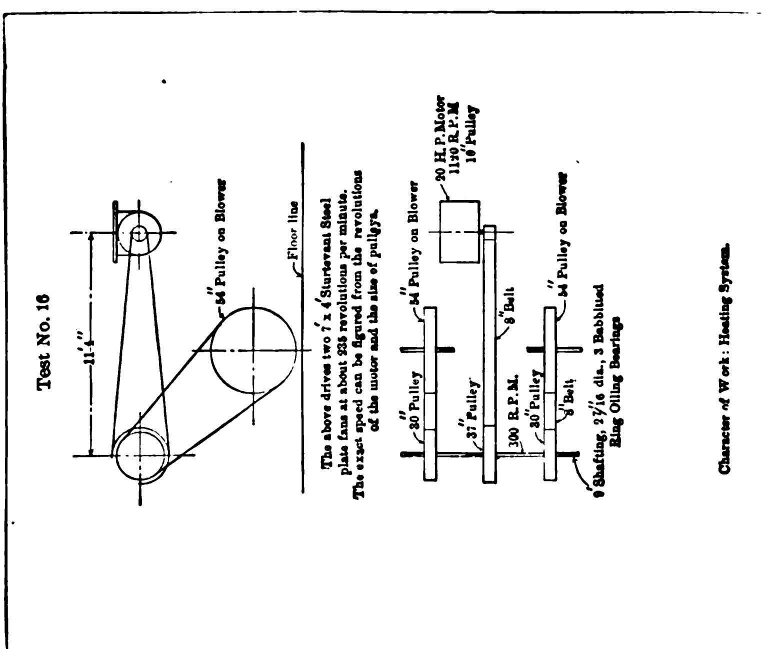


FIG. 181.

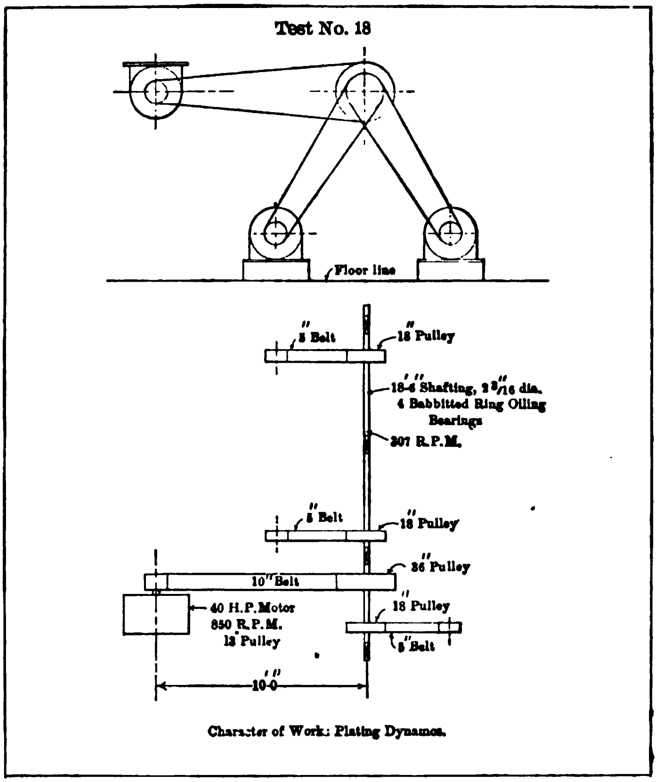

Test No. 18
Floor line
5" Belt
18" Pulley
18'-6" Shafting, 2 3/16" dia.
4 Babbitted Ring Oiling Bearings
307 R.P.M.
5" Belt
18" Pulley
36" Pulley
10" Belt
40 H.P. Motor
850 R.P.M.
12" Pulley
18" Pulley
5" Belt
10'-0"
Character of Work: Plating Dynamos.

FIG. 183.

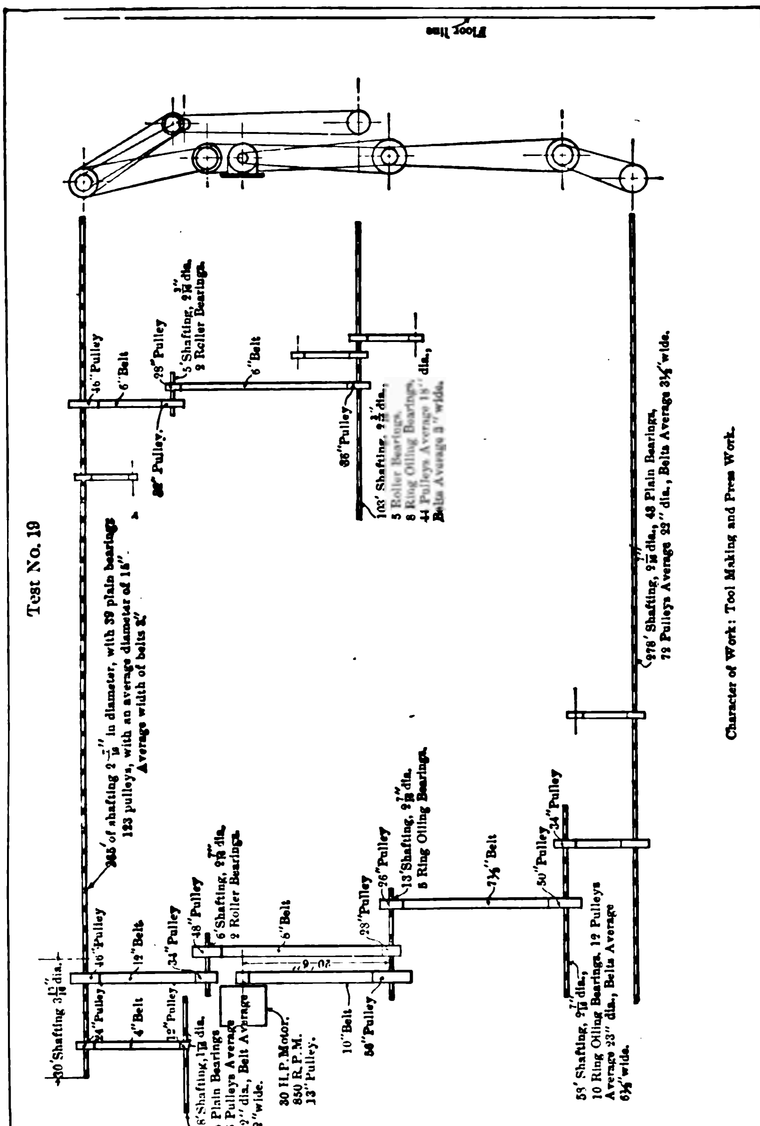

Test No. 19
Floor line
265' of shafting 2 15/16" in diameter, with 39 plain bearings
123 pulleys, with an average diameter of 16"
Average width of belts 5"
46" Pulley
6" Belt
28" Pulley
5' Shafting, 2 15/16" dia.
2 Roller Bearings.
6" Belt
36" Pulley
36" Pulley
103' Shafting, 2 1/2" dia.,
5 Roller Bearings,
8 Ring Oiling Bearings,
44 Pulleys Average 18" dia.,
Belts Average 3" wide.
278' Shafting, 2 15/16" dia., 48 Plain Bearings,
72 Pulleys Average 22" dia., Belts Average 3½" wide.
Character of Work: Tool Making and Press Work.
30' Shafting 3 15/16" dia.
24" Pulley
4" Belt
12" Pulley
46" Pulley
12" Belt
34" Pulley
48" Pulley
6' Shafting, 2 15/16" dia.
2 Roller Bearings.
6" Belt
23" Pulley
26" Pulley
13' Shafting, 2 7/16" dia.
8 Ring Oiling Bearings.
7½" Belt
50" Pulley
34" Pulley
20'-6"
16' Shafting, 1 15/16" dia.
4 Plain Bearings
5 Pulleys Average
12" dia., Belt Average
2" wide.
30 H.P. Motor.
850 R.P.M.
13" Pulley.
10" Belt
56" Pulley
58' Shafting, 2 7/16" dia.,
10 Ring Oiling Bearings. 12 Pulleys
Average 23" dia., Belts Average
6½" wide.

FIG. 184.

TABULATION OF MOTOR TESTS.

(See sketches of tests, Nos. 7 to 19 inclusive.)

DATA. Number of Test.	Location. Building.	Location. Room.	Location. Kind of work.	Conductor. Size B. & S. gauge.	Conductor. Length of line per Phase in feet.	Energy at switch-board A. K. W.	Energy at switch-board A. H. P.	Average Motor Load. Input B. K. W.	Input B. H. P.	Output C. K. W.	Output C. H. P.	Nominal Rating of Motor in H. P.	Transmission Losses. Electrical. Line loss $D=A-B$. K. W.	Line loss H. P.	Motor loss $E=B-C$. K. W.	Motor loss H. P.	Mechanical. Shafting F. K. W.	Shafting F. H. P.	Shafting and Machines Idle, G. K. W.	Shafting and Machines Idle, G. H. P.	Efficiencies. %. Line $(a)=\frac{B}{A}$.	Motor (Commercial) $(b)=\frac{C}{B}$.	Electrical* $(c)=\frac{C}{A}$.	Water rate per hour at Motor Pulley. Per K. W.	Water Per H. P.	Coal rate per hour at Motor Pulley. Per K. W.	Coal Per H. P.	Com-bustible rate per hour at Motor Pulley. Per K. W.	Com-bustible Per H. P.	Horse-power required per foot of shafting.
7	17	Rod shop	Automatic screw machinery	No. 00 " 4	250 300	34.4	46.1	33.2	44.5	26.85	36.	27.5	1.2	1.6	6.35	8.5	12.9	17.3	21.6	29.	96.3	81.	78.	28.6	21.3	3.28	2.45	2.72	2.03	.029
8	10	105	Gen'l machining.	" 0000 " 6	520 150	13.35	17.9	13.	17.43	11.05	14.8	15.	.35	.47	1.95	2.6	5.6	7.5	16.4	22.	97.5	85.	82.8	27	20.2	3.09	2.31	2.57	1.92	.029
9	19	Cabinet lock shop	Gen'l machining, polish'g & buff'g	" 00 " 0	250 700	36.	48.3	34.5	46.3	28.5	38.2	40.	1.5	2.	6.	8.1	....	....	23.5	31.6	95.8	82.5	79.	28.3	21.1	3.24	2.42	2.68	2.00	.041
10	24	Iron Foundry	Cupola blower & heating system.	" 000	1,400	31.2	41.8	30.	40.2	24.85	33.3	30.	.8	1.07	5.15	6.9	...	....	2.4	3.22	96.2	83.	80.	27.9	20.8	3.2	2.39	2.66	1.96	
11	2	25...	Plating dynamos and exciter....	" 00 " 6	390 270	5.14	6.89	5.	6.7	4.05	5.43	10.	.14	.19	.95	1.27	.. ..	....	.93	1.25	97.3	81.	79.	28.3	21.1	3.24	2.42	2.68	2.00	
12	4	44............	Polishing and buffing	" 0000 " 0	500 120	33.1	44.4	32.5	43.6	28.2	37.8	40.	.6	.8	4.3	5.8	21.1	28.3	22.7	30.5	98.2	87.	85.2	26.2	19.5	3.01	2.24	2.49	1.86	.091
13	2	24............	Polishing and buffing	" 00 " 2	390 100	27.2	36.4	26.5	35.5	22.55	30.2	30.	.7	.94	3.95	5.3	12.3	16.5	17.9	24.	97.6	85.	83.	26.8	20	3.08	2.3	2.56	1.91	.063
14	4	44............	Ventilating system	" 0000 " 2	400 200	26.42	35.4	25.7	34.4	20.7	27.7	30.	.72	.96	5.	6.7	....	....	......	......	97.5	80.5	78.4	28.5	21.3	3.27	2.44	2.71	2.02	
15	2	24...............	Ventilating system.	" 4	350	27.2	36.56	26.56	35.7	21.36	28.7	20.	.64	.86	5.2	7.	....	...	......	......	97.7	80.5	78.7	28.4	21.2	3.26	2.43	2.7	2.02	
16	10	101.............	Heating system..	" 0000 " 4 " 8	520 80 240	25.8	34.7	24.4	32.8	19.9	26.75	20.	1.4	1.9	4.5	6.05	....	....	......	......	94.8	81.5	77.2	28.9	21.6	3.32	2.47	2.75	2.05	
17	18	Smith shop	Drop forging.....	" 00 " 0 " 2	250 100 300	18.47	24.8	18.1	24.3	15.65	21.	30.	.37	.5	2.45	3.3	....	....	15.	20.1	97.8	86.5	84.5	26.4	19.7	3.03	2.26	2.52	1.88	
18	4	45..............	Plating dynamos.	" 0000 " 0	500 140	22.3	29.9	22.	29.5	19.	25.5	40.	.3	.4	3.	4.	....	...	5.6	7.5	98.6	86.5	85.2	26.2	19.5	3.01	2.24	2.49	1.86	
19	17	Tool, mach., & press shop.	Tool making and press work.....	" 00	310	36.	48.25	35.6	47.7	28.8	38.6	30.	.4	.55	6.8	9.1	14.9	20.	33.5	45.	98.5	81.	80.	27.9	20.8	3.2	2.39	2.66	1.98	.026
																							Ave...	27.65	20.62	3.17	2.37	2.63	1.96	

* Ratio of energy delivered at motor pulley to energy at switchboard.

Discussion.

Mr. S. S. Webber.—I would like to ask the author if any examination was made of the vanes in the turbines to determine whether cutting was taking place due to the rapid passing of steam through. It seems to me that would be one of the things that would take place.

Mr. Waldron.—The evidence for nearly a year shows nothing of the sort.

Mr. Pomeroy.—On page 1008 the author states that the turbine is working non-condensing between 7 and 10 A.M. and between 3 and 5 P.M., and I want to know whether there is any record of the steam consumption non-condensing?

Mr. A. M. Mattice.—My connection with the company which built the turbo-generator described by Mr. Waldron, and which met with an accident at the Yale & Towne Works enables me to lay before the Society some facts which may be of interest, particularly to those members who have occasion to use steel forgings for purposes which require great care in the selection of material. The core of this revolving field was a steel forging a trifle less than two feet in diameter. The material was annealed nickel steel, made to specifications which included a requirement of at least 40,000 pounds per square inch elastic limit and 25 per cent. elongation in a standard test piece ½ inch diameter and 2 inches long between gauge points.

The fact is doubtless familiar to many members that steel forgings frequently show very fine cracks running parallel to the axis of the forging. Sometimes these are superficial, but in other cases are quite deep. I have noticed these cracks more in nickel than in carbon steel. These cracks often show up during rough turning, but the finer ones are frequently developed only by the finishing cuts.

We had had occasion to reject several nickel steel forgings for this class of defect previous to the building of the Yale & Towne machine. No defects were discovered at our works, but an examination of the fractured forging showed that there were a number of very deep cracks reaching to several inches below the surface, the difference in appearance between the original cracks and the new fractures being very marked.

There were no fractures at the points which were subjected to the greatest stresses due to centrifugal force, but the fractures were extensions of the original cracks; one fracture being at the point where there would have been less stress than at any other point if the metal had been sound.

An investigation as to why the cracks had not been discovered during the machining of the forging in the electric works showed that such cracks may or may not show up during machining, according to circumstances. A crack may not be noticeable to the naked eye, but may be readily traced by a magnifying glass. A crack may not be visible in smooth tool finish, but may be visible to the naked eye or perhaps only by the aid of a magnifying glass after highly polishing. Even after polishing, a crack may not be visible, but will be shown up by etching the surface with diluted nitric acid. Finishing by grinding will hide a crack which a smooth tool finish may expose, presumably because the grinding operation drags the surface of the metal across the crack.

In examining the surface of a forging for the purpose of discovering possible cracks, care should be taken to discriminate between true cracks and what at first sight might be mistaken for cracks. Sometimes after machining, sometimes after polishing, and sometimes only after etching with acid, sinuous lines will be found, which might be easily mistaken for cracks, but where the metal is perfectly sound. These are what are sometimes called by steel makers "white streaks." The cause of these I am unable to explain, but I presume that they are caused by the flow of metal during forging. As far as my experience goes, these streaks appear only near the surface of the rough forging, and disappear at a moderate depth. These streaks may generally be distinguished from cracks by the fact that the streaks are in general wavy and run in various directions, while the cracks are fairly straight and in general run nearly parallel to the axis of the forging.

Test pieces taken from the fractured forging showed a very considerable difference in the quality of the material at the periphery and at the bore for the shaft; the elastic limit being much higher at the bore than at the periphery, and the elongation very much less. Whether this difference has anything to do with the production of surface cracks is a question for steel makers to solve. An analysis of the steel showed considerably higher silicon near the bore than at the periphery, but otherwise the analyses were practically identical.

The results of an investigation of the cause of the accident cited by Mr. Waldron has convinced us that ordinary methods of inspection and test of steel will not suffice in cases where a fracture might lead to serious results. A test piece taken from an extension of the forging in the usual manner, may or may not represent the true nature of the forging. This test may show up well, and at the same time the forging may be ductile in one place and very brittle in another.

In order to guard against a repetition of such an accident we now require at least two test pieces to be taken from each forging for turbo-generator fields; one from near the periphery and one from near the bore, before preliminary acceptance at the steel works. We also require the surface of the forging to be polished and etched with acid to explore for possible cracks. During the machining operations at the electric works a number of slots and holes are cut in the forgings to receive the field winding and to provide for ventilation. Advantage is taken of this to obtain further test pieces, thus enabling us to ascertain the true quality of the steel all the way through. The tests made on specimens so obtained have led to a number of rejections of forgings.

For fear, however, that tests and inspection may fail to locate a defect in the rotor of a turbo-generator, we now test all such generators in our shop at 20 per cent. over normal speed, thus adding 44 per cent. to the stresses due to centrifugal force. Where the failure of the governor might cause a reciprocating engine to reach 20 per cent. overspeed in a comparatively short time, the high ratio between the inertia of the turbo-generator and the driving force causes fluctuations of speed to be very gradual, and a turbine would be so long in reaching overspeed as to give the attendants plenty of time to shut off steam. It may be remarked that the change in the sound due to a change in speed of a turbo-generator, either higher or lower, is so marked that an attendant instantly notices it. The inertia of the turbo-generators will be appreciated by the fact that the 400 kilowatt machines, such as used by Yale & Towne, run for nearly twenty minutes after steam is shut off.

Mr. Waldron mentions the fact that practically no damage was done to the building or to the bystanders by the accident to the generator. This is accounted for by the construction of the stationary armature which is built up of sheet steel punchings which are lapped over each other, breaking joints, thus forming a structure of such immense strength that the bursting of the rotor running at 3,600 revolutions per minute was insufficient to rupture it.

Many people would probably lose faith in a comparatively new type of apparatus like a turbo-generator after an accident such as the author has described. Mr. Waldron, however, took the matter very philosophically, and seems to have reasoned as follows:

The accident was plainly due to flaws in the material and not to fault of design. Similar accidents frequently happen to the flywheels of reciprocating engines. In the case of a turbo-generator the construction is such that the effects of an accident must be confined within the machine itself instead of damaging surrounding property. Therefore, aside from other considerations, a turbine outfit is the preferable form of motive power. It is a significant fact that the Yale & Towne Manufacturing Co. shortly after the accident, and before the outfit had been repaired, ordered another turbo-generator which is an exact duplicate of the one to which the accident occurred, thus showing their faith in this type of apparatus.

Mr. W. L. R. Emmett.—I would like to ask one or two questions of the author of this paper. He speaks of the lubrication of the bearings. I would like to know whether any of the special types and methods used in the European turbines have been used in these bearings. I would like also to know whether the steam is entirely free from oil when it enters the condenser. I would also like to know the pressure of the oil used in the bearings.

The report which has been read concerning the condition of steel forgings used in the field of this generator indicates the character of imperfections which are liable to occur in any forging. I consider it much more desirable where possible, to use sheet steel punchings for a structure of this sort. Sheet steel is a fibrous, laminated structure, and is not subject to cracks. The strength of a structure built up of punchings is almost certain to be fully equal to the tested strength of the material from which it is built.

Mr. C. V. Kerr.—There are just three points which I would like to take up in this paper. I want to call attention first to the statement as to the guarantees made on page 1001. It is stated there that the guaranteed economy was 16½ pounds of water per electrical horse power at the switchboard with 28 inches of vacuum, 40 degrees Fahr., superheat, and 155 pounds gauge pressure. Upon page 1016 on the 400 kilowatt test, the steam pressure was 151 pounds, the superheat at the throttle 20 degrees, the vacuum a little less than 27 inches, and the water per electrical horse power was 16.53 pounds. Again, on page 1018, on the overload test, where the steam pressure was a little less than 153 pounds, the superheat at the throttle 18 degrees, the vacuum 27½ inches, and the water 16.18 pounds. Mr. Waldron has not stated on which side of the guarantee the result showed. Hence I am privileged to call attention to this matter. Again, on page 1007, he speaks of the failure of the rotating field. It was my privilege to take part in a sort of mathematical autopsy of this field, and I may say that after calculating the stresses in several different ways, the maximum was less than 14,000 pounds per square inch, which gave a factor of safety within the elastic limit of about 3 and ultimate strength of about 6.

On page 1008 is mentioned another fact in connection with the operation of the turbine which is interesting from the standpoint of thermodynamics. "The writer has also found that the temperature in the exhaust chamber of the turbines varies with the different loads, and at full load and overload there is more or less superheat, whether running condensing or non-condensing." We must take that in comparison with the low degree of superheat at the throttle, and the fact that we have but 27 inches of vacuum. In that connection I simply wish to call attention to some tests which have come under my notice. For instance, a simple engine, non-condensing, shows superheat in the exhaust as calculated from the water rate, and the curve of these tests would show that for a superheat of 70 degrees the exhaust would come out of the engine dry. What would it do in the condensing engine? Another test with 120 pounds gauge, 26 inches vacuum, showed moisture in the exhaust, and the curve of these tests would show that with 265 degrees superheat the exhaust would come out of the engine dry, even with 26 inches vacuum. And I might call attention to the fact that if you look at the results of some of Professor Ewing's tests you will find with non-condensing work as much as 100 degrees of superheat in the exhaust. To show that excessive superheat is not always a really good thing, a German engineering society reports a test on a 30 horse power turbine, steam pressure 88 pounds, but the superheat ran the temperature to 932 degrees, the steam per horse power rate was 25.7, while the exhaust had a temperature of 437 degrees above atmospheric temperature. This was non-condensing, and running at full load. It is the opinion of at least two of the highest authorities that superheat should stop at the point where the exhaust is turned out dry.

These are interesting points to me, and I believe that the future will see a great deal of attention paid to them. Even if this limit of efficiency should prove true in practice, we have to consider that we are making superheat at the expense of coal, and very likely these authorities are right in taking the exhaust dry for the maximum economy, when we take into account the cost of the plant.

*Mr. Waldron.**—No test has yet been made in reference to the economy of the turbine running non-condensing, all of the exhaust steam being utilized in the winter time for heating buildings.

In reference to superheat, no systematic or accurate tests have been made. It was noticed particularly by me, during the different tests reported in this paper.

As to the guarantee, I did not think it would be necessary to state which side of the guarantee was reached by the turbo-generator, as an inspection of the tests will show that with a lower degree of steam pressure, superheat and vacuum than was specified in the guarantee, the average economy for all loads was less than the guarantee.

A Member.—I should like to ask the following questions:

1. Does the oil used go into the exhaust steam?

2. Are the bearings made of a number of concentric sleeves?

3. What oil pressure is used on the bearings?

Mr. Waldron.—1. Cylinder oil, to the extent of about ½ gallon per week, goes into the exhaust steam.

2. The bearings are, I think, made of three concentric sleeves, but I am not in a position to discuss the details of design, as I am not familiar enough with them.

3. Pressure of oil on the bearings, I should judge, was from 18 to 28 inches.

* Author's Closure, under the Rules.

No. 988.*

ALTERNATING CURRENT MOTORS FOR VARIABLE SPEED.

BY W. I. SLICHTER, SCHENECTADY, N. Y.
(Junior Member of the Society.)

1. THE impression is very general that a variable speed cannot be obtained with an alternating current motor, and that if an alternating current plant is to be installed, the idea of obtaining a variable speed drive of any of the tools must be abandoned. This is not so, and the object of this paper is to show the possibilities of this type of motor, and to point out its limitations.

But it must be understood in the first place that it is not claimed for the alternating current motor that it can compete with the direct current type where continual variations of speed, throughout a wide range, are required, as the latter motor is usually superior in efficiency under these conditions.

2. Let us assume, then, that the problem to be solved is a case where an alternating current plant is desirable for general reasons, such as distance of transmission or availability of power, and that a considerable amount of the power is used in constant speed work, but a certain portion of the work requires a variable speed. What is the most appropriate and most efficient method of obtaining the variable speed?

3. The speed of an alternating current motor may be controlled in a number of ways:

(*a*) By varying the potential applied to the primary of a motor having a suitable resistance in the secondary.

(*b*) By varying the resistance in the secondary circuit.

(*c*) By changing the connections of the primary in a manner to change the number of poles.

(*d*) By varying the frequency of the applied voltage.

---

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

For the benefit of those not familiar with the polyphase induction motor, a general view of its characteristics may be desirable.

4. These characteristics are very similar to those of the continuous current shunt motor—that is, at a constant impressed voltage and frequency the speed tends to be constant, and a considerable change in load will not cause an appreciable change in speed. As the load increases, the speed drops gradually to a critical point, usually about 15 to 20 per cent. below the normal value, and then the motor breaks down completely if the load is any further increased. The same action occurs exactly if the load is kept constant and the voltage is decreased. But if the frequency of alternation of the impressed voltage is decreased, the speed will decrease in exactly the same proportion. That is, for a given frequency and a given number of poles in the motor, the speed is practically fixed and independent of all other effects.

The one exception to this last rule is the effect of the resistance (or losses) in the secondary (usually the rotating) member.

5. The drop in speed from the synchronous value is directly proportional to these losses. Thus, by increasing the resistance of this circuit, any desired speed may be obtained at the expense of these losses. With the increased resistance, the speed at which the motor breaks down may be reduced to a very low value, even to zero speed. Thus, by reducing the voltage applied to the motor for a given torque, the effect is produced of overloading it, and the speed drops.

These characteristics are equally true for the two-phase or three-phase motor, of course, as the two motors are practically identical in their construction.

6. In this connection it should be remembered that a variation of an alternating voltage may be obtained by means of a reactance or compensator with a very small loss of energy, whereas with a continuous voltage the loss of energy is usually proportional to the variation in voltage.

Taking up these methods in the order enumerated, we will analyze their characteristics.

7. *Potential Control:* In this a suitable reactance or "compensator" reduces the line voltage to the fractional value desired. In this reduction the energy lost is only about 5 per cent. of the amount transformed.

The induction motor should have a very large resistance in the secondary, which is preferably of the squirrel cage type. This resistance gives the motor a speed characteristic such that its full load speed is some 10 per cent. less than that of a normal motor, and as the load is increased, the speed will fall to about 30 per cent. of this value without the motor "breaking down" or falling out of step, which in the normal motor usually takes place at about 80 per cent. of the full load speed.

8. Such a motor would have the following characteristics, assuming its synchronous speed as 1.00, and the voltage applied as 100. (This is based on a 50 horse-power, 40 cycle motor, at 800 revolutions per minute, as an instance.)

For constant full load (50 horse-power) torque at various speeds:

	Speed.	Volts.	Efficiency.	Losses, Motor.	K. W. Comp.
Full load speed...........	.89	100	81	8.8 K. W.	0.0 K. W.
Three-quarter load speed..	.67	66	59	18.5 "	1.0 "
One-half load speed.......	.45	57	37	32.0 "	2.0 "
One-quarter load speed....	.22	56	17	45.7 "	3.5 "
Normal motor (full speed).	.98	100	88	5.0 "	0.0 "

From this we see the principal and worst characteristic of this scheme. The increased losses in the motor (thus increased heating) with the decreased speed. This means that the motor must be larger than normal.

9. *Rheostat Control:* In this scheme the secondary or rotor must have a definite winding (as opposed to the squirrel cage, which is cheaper) with slip rings and brushes to lead out the current. The friction and resistance losses due to these brushes decrease the efficiency of the motor somewhat. The secondary is usually wound for a higher voltage and less current than in the standard or normal motor, to minimize these losses. The action of this method is based on the principle that, in an induction motor, the drop in speed for any given torque is proportional to the resistance of the secondary circuit.

10. This scheme would show the following characteristics for the same motor as before at 50 horse-power torque, constant:

	Speed.	Volts.	Eff.	Losses, Motor.	Rheo.
Full load speed	.96	100	86	5 K. W.	0.0 K. W.
Three-quarter load speed............	.72	100	65	5 "	9.0 "
One-half load speed.................	.48	100	43	5 "	18.5 "
One-quarter load speed	.24	100	22	5 "	28.0 "
Normal motor (full).............	.98	100	88	5 "	0.0 "

As will be seen, this method gives a higher efficiency throughout, but particularly excels the previous method in having so much smaller losses in the motor itself, thus permitting of a smaller design and less danger of damage. The losses are concentrated in a rheostat, which is a cheaper piece of apparatus and less liable to damage, being of iron and asbestos usually, instead of high grade insulating materials, as in the motor proper.

11. *Changeable Poles:* By using a pitch of winding which is commensurable with two numbers of poles, we may build a motor which will operate with either 4 or 8, 6 or 12, etc. poles, by a slight change of the connections. Or by a more intricate arrangement of windings a change from 4 to 6, 6 to 8, etc., may be made.

In this arrangement it is necessary to use a squirrel cage armature, since it is suitable for any number of poles, and the pitch of the primary coils has to be made some compromise value between the normal pitch of the two combinations, so it is usually not the best or most effective pitch for either number of poles. Therefore the constants of this motor should not be expected to be as good as those of the standard motor.

Of course such a motor operates advantageously only at two speeds corresponding to the synchronous speeds of the two arrangements. Thus, a 12 and 6 pole motor at 40 cycles would operate at either 400 or 800 revolutions respectively.

If a wider range is desired, the potential control scheme first mentioned may be combined with it.

12. For a motor operating at full and half speeds, say with 6 and 12 poles for 800 and 400 revolutions, we would have:

	Volts.	Eff.	Losses.
Full speed, 50 horse-power..............	100	86	5.8
Half speed, 25 horse-power...............	100	74	6.6

Thus, for full load torque at half speed we get an efficiency almost double that obtained with the other methods, but what losses there are are in the motor itself, as in the first case. The losses are about the same in the two cases, the speed thus the ventilation being half in one case, the heating is greater at the lower speed.

13. *Variable Frequency:* Every induction motor tends to run at synchronous speed—that is, at a speed equal to $\dfrac{60 \times \text{frequency.}}{\dfrac{\text{Poles}}{2}}$

Thus, if a different frequency is impressed on the motor, it will run at a different speed. Some installations have been made where two or three alternating current generators are used to obtain different frequencies, and these circuits are carried around the shops by various sets of lines (usually three in each set) and the motor connected to the lines giving the frequency and speed desired. For normal losses in the iron the voltage must vary with the frequency. Thus for full and half speed we have :

	Volts.	Eff.	Losses.
Full speed, 50 horse-power	100	88	5
Half speed, 25 horse-power	50	87	2.8

14. Generators have been built having two stationary armatures in the same frame and two revolving fields, with a different number of poles on the same shaft to give the multiple frequency desired. An application of this principle, which is very pretty theoretically, is that of a very small variable speed induction motor (whose losses are negligible) which drives a commutator feeding the primary of the load machine; by a suitable control of the little motor any desired frequency may be supplied to the load machine from zero to full value, thus it may be started and run at any desired speed. A variation of this is to attach the commutator to the shaft of the load machine and the brushes to the shaft of the controlling motor, thus when the load machine is standing still the brushes revolve at almost full speed on the commutator, and a very low frequency is obtained in the commutated circuit. As the load machine speeds up, the difference in the speeds of the commutator and the brushes decreases, and hence the frequency increases until that time when the commutator and brushes are revolving together at the same speed when there is no commutation and the load machine receives full frequency.

Summary.

15. From these descriptions it will be seen that the changeable pole and variable frequency methods are the most efficient, but do not permit of a variation through a wide range of speed. The rheostatic control is the simplest and easiest of control, giving a range from standstill to full speed, but is not as efficient as the first two, although more efficient than potential control. The last mentioned has the disadvantages of low efficiency and considerably increased heating in the motor itself, and is also unstable at low speeds, say below one-third speed. That is,

a small variation in torque or a smaller variation in voltage will cause a considerable variation in speed.

16. The potential control is used where moderate variations in speed are wanted, not reaching to less than half speed for instance, and where the load is intermittent, not giving the motor a chance to get too hot. Its great disadvantage is the amount of current it takes at starting, which causes considerable disturbance in the supply circuit, flickering of lights, etc., due to the drop in voltage. The motor used is a cheaper one to build (for the same size) than the others, but if anything like continuous running is desired, the motor must be larger, thus much of this advantage is lost.

17. One advantage of this motor is that it may be totally enclosed for use in powder mills, oil refineries or where much dust or corrosive vapor is encountered, as it may be controlled from a distance without increasing the number of wires.

18. The rheostatic method is particularly adapted where frequent starting and low speeds are required, as it causes no unusual drain on the supply system when starting. Thus it is used for hoists, elevators, etc.

The changeable pole system has the same disadvantages in starting as the potential control. For long-continued running at only two different speeds it is excellent, and has constants comparable with those of a continuous current motor.

19. To vary the frequency of alternation for the motor requires an increased investment in generating station or auxiliary apparatus and line copper, and the greater the number of speeds desired, the greater this complication; but in its action and economy it is equal to any.

One point which is important to bring out is that with the changeable pole and changeable frequency systems the motor will not vary appreciably from the set speed for changes of load, while with either potential or rheostatic control, a change of load will cause an appreciable variation from the desired speed, requiring a readjustment of the potential or resistance to bring the speed to the desired value again.

DISCUSSION.

Mr. George W. Colles.—The interesting summary here presented of the different attempted solutions of the variable-speed induction-motor problem serves to emphasize the fact that the problem has not yet been solved. Practically, then, the "general impression" (to use the author's words) "that a variable speed cannot be obtained with an alternating current motor" is in the main correct.

It seems to me that the author does not place before us, as he should before a mechanical rather than electrical Society like ours, the bearing and significance of the problem in hand, but plunges, so to speak, "in medias res" or in plain United States, has given us a magnified view of the center of the picture with no perspective of the whole. At the risk of repeating what everybody knows, I venture to supply in a few words this omission.

Ten years ago there was no demand for an alternating-current motor. At that time all our electric power work was performed from and on direct-current circuits. Not that the utility of such a motor was not recognized—as it certainly had been long before even direct-current motors came into use—but simply that it had not been invented. The synchronous alternating motor, which is an alternating-current generator turned around, was and is "out of it," for it requires a commutator or exciter even when it can be made self-starting, which normally it is not.

About that time the induction-motor with squirrel-cage armature was invented by von Dolivo-Dobrowolsky in Germany. But this itself was a product of, and depended for its existence on, the polyphase system of transmission, first patented by Tesla in 1888, and which we owe, commercially speaking, unquestionably to him, as much as we owe the telegraph to Morse. The invention of this system stands forth as the grand electrical invention of our generation, and did more to develop electricity as a means of power-transmission than anything since the invention of the dynamo. What this means will be evident when we consider that without it our enormous schemes for power-development and long-distance transmission would have no existence.

The sole reason for this is that the polyphase current is a kind of link between the direct and alternating currents, partaking of the characteristics and having the principal advantages of both. For lighting the alternating current is perfectly satisfactory, hence almost the sole advantage of polyphase current as compared with the alternating is that it provides for power-transmission. The polyphase current finds its *raison d'être*, then, in the polyphase motor—practically the induction-motor, as that is the only one in extensive use; and conversely, the induction-motor finds its excuse for existence in the polyphase current.

It need scarcely be said that the great advantage of the alternating current lies in the economy it offers for long-distance transmission, by reason of its ready transformability in line-tension by stationary, cheap and highly economical apparatus. As long, therefore, as no long-distance transmission question is present, there is no question about motors, for in point of flexibility and economy the direct-current motor leaves hardly anything to be desired.

The direct-current motor has, however, one important and apparently insuperable defect, the commutator, which adds much to the expense and renders the motor liable to injury. The induction-motor has the great merit and advantage of having no commutator, and, in its simple form, no exposed conductors or sliding connections at all.

As the alternating or polyphase (virtually a compound alternating) current is evidently with us to stay, and increasingly so, the need for an induction-motor to replace the direct-current motor for *all* purposes becomes increasingly urgent. The use of direct-current motors on a polyphase system through the intermediary of rotary transformers and the like can never be regarded as anything but an awkward makeshift, because necessarily it involves the use of *two* motors, each of full capacity, to do the work of one, together with all that that implies, double cost, double attendance, double repairs, double transmission-losses. And the smaller the proportion of direct-current motors, the more awkward does it become.

As an instance of this, I may mention that the Montreal Heat, Light and Power Company has recently given its customers notice that no more contracts for direct-current motors would be renewed, so it is a matter of very serious concern to Montreal power users to get along with direct-current motors in future. The power, which is supplied entirely from outside water-power, will henceforward be obtainable only as polyphase current.

The main reason why it is so hard to dispense with direct-current motors is because the ordinary inductor-motor cannot be run at variable speed. Where only a fixed speed is required, as for running a line-shaft, of course this is no disadvantage but rather an advantage, but for numerous purposes the machine to be run *must* be capable of different speeds, and a motor which runs at different speeds must, of course, do so at reasonable efficiency.

Of the four possible methods given by the author, the first is undoubtedly the simplest, as here it is merely necessary to insert a compensator in circuit with the motor. This, however, is decidedly unsatisfactory, as, owing to the necessity of having a high-resistance secondary, even the full-speed efficiency of the motor is largely reduced, while at quarter-speed it is but 17 per cent., and even at half-speed only 37 per cent., while at the same time the heating of the motor due to all this waste of energy is something frightful, and practically prohibits its use at those speeds.* Hence this is a very imperfect, besides unsatisfactory, solution of the problem.

All the other solutions given may be labeled at once *too complicated.* Not that they are so for use as makeshifts, for *some* solution must be adopted, but they cannot be regarded as other than makeshifts. The resistance-in-secondary method is the only one that has been used to any extent. This completely nullifies the meritorious natural features of the motor, whose complete freedom from exposed contacts, commutator and slip-rings, and simple squirrel-cage made it much simpler, and therefore cheaper, than the direct-current motor; and it now becomes considerably more expensive and delicate, and considerably less efficient. The efficiency is now but 65 per cent. at $\frac{3}{4}$ load, 43 per cent. at $\frac{1}{2}$ load, and only 22 per cent. at $\frac{1}{4}$ load. This method is also of extremely limited application and unsatisfactory from every point of view.

The pole-changing method is still more complicated in practical development and still more limited in application, as here we have only two or three fixed speeds with no variation.

The complication of the frequency-changing plan may be obvious when we consider that for every variation of speed, or rather every different speed, we require *three*, or at least *two*, more line-wires and another set of generators at the station. Consider that three or four line-wires for *one* speed are already too many, and then think of adding say six more line-wires to that, all to obtain two more speeds!

* The rapid decrease in efficiency and accompanying heating with decrease of speed is due primarily to the large increase in the so-called wattless current, which is a necessary consequence of the reactance brought in with the compensator, and inseparable therefrom.

The other, or "theoretical" proposed variation of this idea, is indeed theoretically almost perfect; but unfortunately involves the two mountainous practical difficulties of an *auxiliary motor* and *rotating-brushes* (including, of course, a commutator), either of which is prohibitory.

Unquestionably the frequency-changing solution is *the* solution *par excellence*, could we but reach it; it is the frequency that fixes the speed of the motor, hence the frequency that stands in the way of changing it. *But how change the frequency?*

It is just here that the art sticks, and it is safe to predict that the man who invents a method for universal frequency-transformation without introducing more difficulties than those he obviates, will have a fortune at his command. There seems absolutely no outlook in this direction, as I have pointed out in another place.*

Induction-motors are much more largely used in Europe than America, for the reason that they are ahead of us in polyphase-current development; many of their railways are equipped with it. For railway work the second, or rheostat method of speed variation is, I believe, in most general use. Its great objections in work like railways and elevators, where frequent starting and stopping under heavy load is required, are still further magnified, and the average efficiency of the motor reduced to a very low figure indeed.

Practically, the solution adopted in this country, is ordinarily to introduce variable-speed gearing between the motor and the driven machine, while the motor itself remains at fixed speed. This, while in fact no solution at all, but a "dodge," is probably the most satisfactory mode of settling the matter, where it is applicable—which it is not in all cases—so long as we can have nothing better, and the fact that this circumvention is adopted in preference to any of the proffered "solutions," shows that the latter are not what they claim to be.

This question of finding a variable-speed motor to run on polyphase circuits is no academic question, but one which the mechanical engineer will have to face, and the electrical engineer will have to solve, in the near future. At the present rate of development, it is clear that within a few years more our rail-

* "Frequency-transformation," Jour. Frank. Inst., July, 1901 (in art. *Rotary Transformers*).

ways and elevators will all be run on polyphase or alternating circuits, and some substitute for the direct-current motor must necessarily be found. As moreover the mechanical engineer is obliged with each year to lean more and more on the electric current, and that current a polyphase current, the question of motors is one in which he needs to feel more than a languid interest.

*Mr. Slichter.**—As stated in the first paragraph of the paper, no claim was made that any of the methods described for controlling the speed of an alternating-current motor were equal in economy to the employment of a direct-current motor. It must be acknowledged that speed control is the weak feature of the alternating-current motor as constructed at present. Though it is probable that a variable-speed alternating-current motor will be developed in time, at present we are confronted with the dilemma that alternating-current systems are increasing in application very rapidly and variable speed of such motors can only be obtained by the methods described. The question for the mechanical engineer is, therefore, which of the available methods will best suit my conditions.

Perhaps it would make the subject clearer to give the analogous methods of controlling the direct-current motor in each case.

The most used and best direct-current system of control is the multi-voltage system. In this there are as many economical running speeds as there are voltages. This corresponds either to the variable-frequency or changeable-pole control of the alternating-current. By having two generators and five wires, two economical speeds may be obtained, by constructing the motors with changeable poles two (or even three) other speeds may be obtained, making four or six speeds with only a slight change in the efficiency.

If now it is desired to obtain still further variations from these set speeds, we would manipulate the shunt field of a direct-current motor. This would impair the efficiency somewhat, as with a weaker field the armature would require more current for a given torque, thus increased copper loss.

In the alternating-current motor we would now change the impressed voltage on the motor, and since only a slight change

* Author's Closure, under the Rules.

in speed (varying between the two set speeds) is required, the resistance of the secondary need not be so great and prohibitive as in the case given in the table, thus the efficiency would not be much reduced below the value a direct-current motor would give. For the alternating-current motor to begin with has not the disadvantage of a commutator and the losses appertaining thereto.

If a still greater range of speed were desired, we would insert a resistance in series with the armature of the direct-current motor. Similarly in the alternating-current motor we would connect a resistance in the secondary circuit. The effect on the efficiency would be exactly the same with both the alternating-current and direct-current. The alternating-current motor would have the practical advantage, in that the circuit of this rheostat is entirely independent from the primary, and there is no danger from a ground, while in the direct-current the rheostat becomes part of the main line, and must be as carefully insulated as any part of that circuit.

Thus there is considerable similarity between the two motors, and not so very great a difference in the economy of similar methods. But a great difference may be made by choosing a method appropriate to the service required. Thus in the above combination, four sets of speeds are obtained, with gradations of from 10 to 20 per cent. above and below these set speeds and an efficiency varying between 70 as a minimum and 86 as a maximum.

There are two minor statements made by Mr. Colles with which I wish to take issue. The first is that the decrease of efficiency and increase of heating of the alternating-current motor has anything to do with the compensator. These effects are peculiar to the motor proper, and result from the action of operating the motor at a large overload, which has the effect of causing it to give out its full load torque at a reduced voltage. For a given impressed voltage the motor has a well defined range of load, and if at any voltage, compensator or not, the motor be loaded above this range, large, wattles currents will flow and the motor will become unduly heated.

The other point is that the development of the polyphase-current in Europe is further advanced than in America. This impression is caused by the fact that due to the smaller scale on which most things are undertaken there, the complications of polyphase work, such as railroading, are not prohibitive as they would be here.

American engineers would not equip a railroad, having any considerable traffic, with the cumbersome overhead construction and complicated controlling apparatus which are necessary to obtain the minute speed and torque variations required for railway work, but are working towards the development of a motor which will require only one circuit, and will have the variable-speed characteristics of the direct-current-series motor.

No. 989.*

A METHOD OF TESTING GAS ENGINES.†

BY E. C. OLIVER, MINNEAPOLIS, MINN.
(Junior Member of the Society.)

1. The objects of gas engine tests vary all the way from the simple determination of the brake horse-power developed, to the more extensive problems involving the distribution of the heat supplied in the form of fuel, and the determination of the temperatures at various points throughout the cycle.

Experimenters who have taken up this line of work, seem to have recognized some difficulties in the way of making a really satisfactory test of the latter sort, and most tests which are on record have their results based on some assumptions; the results then can only be accurate to a measure depending on the accuracy of the assumption.

The difficulties referred to are encountered when it is attempted to obtain accurately the weight of air, weight of gas and the temperature of the exhaust gas at atmospheric pressure.

2. The usual method is to measure the air and gas through meters of suitable size, a specially large one being required to handle the quantity of air required by the engine. When these meters are available we are still confronted with their inherent defects; they must first be carefully calibrated under given con-

---

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

† For further discussions on this topic consult *Transactions* as follows:

No. 848, vol. xxi., p. 396: "Test of 125 Horse-power Gas Engine." C. H. Robertson.

No. 875, vol. xxii., p. 152: "Efficiency of Gas Engines as Modified by Point of Ignition." C. V. Kerr.

No. 895, vol. xxii., p. 612: "Efficiency Tests of a 125 Horse-power Gas Engine." C. H. Robertson.

No. 949, vol. xxiii., p. 686: "Temperature of Exhaust Gases." R. H. Fernald.

No. 950, vol. xxiii., p. 704: "Working Details of Gas Engine Tests." R. H. Fernald.

ditions, and this is usually done by comparing them with another "Standard" meter, which is supposed to be correct. When used in the test, the conditions must be the same as during the calibration, or the results cannot be relied upon, and the irregular flow which must be produced by the action of the engine is not conducive to accuracy, even though elastic bags are placed between the engine and the meter.

3. There are tests, however, in which gas meters may be used to give results in a satisfactory way: First, commercial tests in which it is desired to ascertain the gas consumption per horsepower per hour, in order to obtain the expense of operating the engine. In this case the gas will subsequently be paid for by meter, and the consumption by meter is what we desire; second, in cases where other means are not available, the meter can of course be relied upon to give results approximately.

4. The temperature of the exhaust gas has been referred to before in this Society, and was the subject of a paper presented by Mr. R. H. Fernald at the spring meeting last year. It is, I think, recognized that the pyrometer method is not accurate because of the short time required for the gas to pass over the instrument, and the comparatively long time between these passages. The method proposed by Mr. Fernald, although ingenious, would not, I think, give the actual temperature of the exhaust, but might be used as the basis of a calculation leading to an approximate value for this temperature.

5. While engaged in the Mechanical Engineering Laboratory of the University of Illinois, the writer was interested in conducting some tests on a 10 horse-power Otto gas engine, the object being to determine the distribution of the heat supplied by the fuel and the temperature at various points in the cycle.

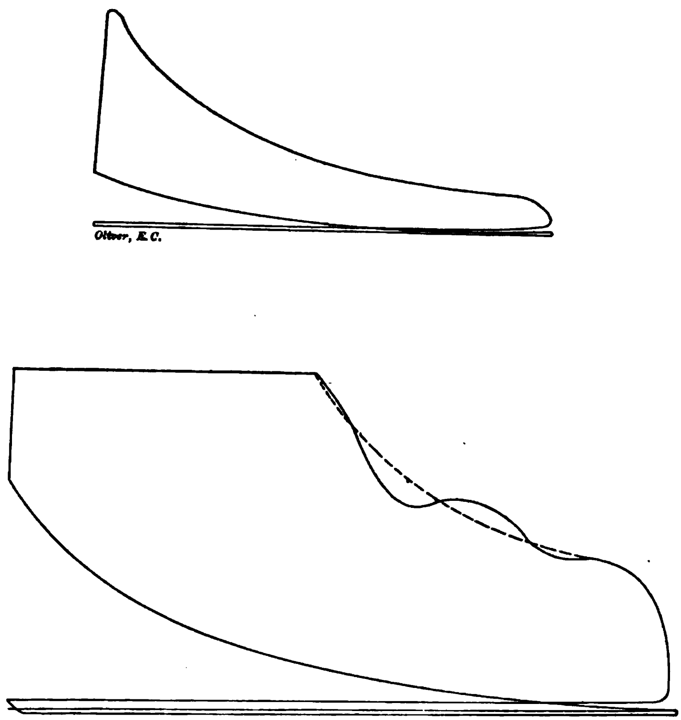
These tests involved the measurements before referred to, and led to the adoption of some methods for obtaining these quantities different from those ordinarily used, and which seemed to give very much more accurate results.

The object of this paper is to describe the methods and apparatus used, and to submit the results of the tests.

The data on which the results were based were as follows: Indicated horse-power; brake horse-power; weight of air; weight of fuel; heat rejected to exhaust; heat absorbed by jacket; total revolutions; total explosions; analysis of fuel; analysis of burned gas; engine constants; duration of test.

Indicated Horse-Power.

6. Two Crosby indicators were used, connection with the cylinder being made by a ½-inch tee and a nipple tapped into the cover of the exhaust valve chamber. One was a special gas engine indicator with a piston ¼ of a square inch area, in which a 240-pound



SAMPLE INDICATOR DIAGRAMS.

FIG. 185.

spring was used. The other was a steam engine indicator with a piston ½ of a square inch area, in which a 60-pound spring was used. This indicator also had a brass collar on the piston rod, to act as a stop when the pressure rose to 100 pounds. Thus two diagrams were obtained, one of which represented the entire cycle to a scale of 1 inch, equal to 240 pounds pressure, and the other, pressures from release through exhaust, suction, and compression to ignition on a scale of 1 inch, equal to 60 pounds pressure.

Fig. 185 shows sample indicator diagrams from each indicator.

Metallic surface cards and brass points were used on the indicators, and the springs were calibrated with steam pressure. A piece of wet cotton waste was kept lying on and around the cylinders, and the pistons were oiled after two or three diagrams.

To obtain the mean effective pressure from the indicator diagrams to be used in computing the indicated horse-power, the mean effective pressure of the lower loop of the low pressure diagram was subtracted from the mean effective pressure of the main or upper loop of the high pressure diagram, the difference being taken as the net mean effective pressure.

Brake Horse-Power.

7. The power of the engine was absorbed by means of a Prony brake, a slightly improved form of which is shown in Fig. 186.

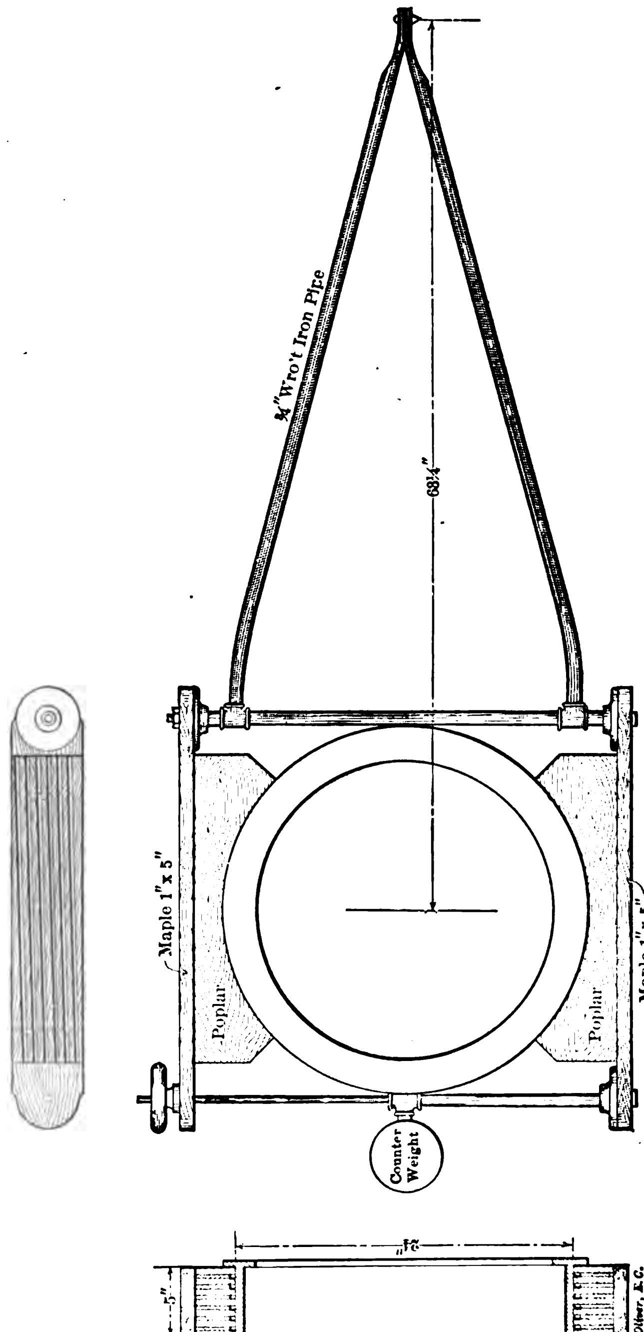
A cast-iron water-cooled brake-wheel 24 inches in diameter and about 4½ inches wide was made to bolt to the fly-wheel in place of the driving pulley.

The brake-shoes were of soft wood (poplar in this case), backed by 1-inch maple pieces. The arm is built up of ¾-inch pipe and fittings, and fastened to the brake-shoes by floor flanges. The lower shoe is connected rigidly to the brake-arm, and the upper shoe is connected by means of a right and left nipple, which is a loose fit in both the tee and the floor flange, so that it may be adjusted with the fingers. A bolt through the vertical pipe connected all rigidly together when in place. The object of the right and left nipple is to allow for wear on the shoes, and permit the brake to be easily removed from the wheel. When in use the load adjustment is made entirely with the hand wheel at the left.

The counterweight, though not a necessary part of the brake, is useful because the pressure as read from the scale is net, no correction being required for the weight of the arm.

The shoes are built up of material ½ and ¼-inch thick, alternating; the ½-inch strips form the bearing surface, the ¼-inch strips being cut away for about ½ inch from the wheel. The strips are also slightly inclined across the face of the shoe, so that the bearing is not continuous across its width, but is a series of bands slightly slanted, the object of this arrangement being to insure smooth and even lubrication.

In operation the brake maintains a steady and uniform load



PRONY BRAKE.

FIG. 186.

with scarcely any attention, is capable of absorbing much more power than that for which it was designed—10 horse-power at 300 revolutions per minute—and has obviated many of the troubles present with some other forms of brakes.

Weight of Air.

8. For measuring the amount of air supplied to the engine a storage tank T of about 90 cubic feet capacity was filled with air compressed to 100 pounds gauge pressure. This air was passed through an expansion or reducing valve to a low-pressure reservoir R of about 10 cubic feet capacity, in which a pressure was maintained of about 1 inch of water, from this reservoir the engine drew its supply during a test.

The pressure and temperatures in the tank T were read before and after a test, and the weight calculated from the formula $P. V. = m R T.$, in which—P is the pressure in pounds per square foot; V is the volume of the tank in cubic feet; m is the weight of air in pounds; R is a constant for the gas = 53.35, and T is the temperature of the gas in Fahr. degrees measured from absolute zero.

The difference in the weights before and after the test represents the amount of air consumed.

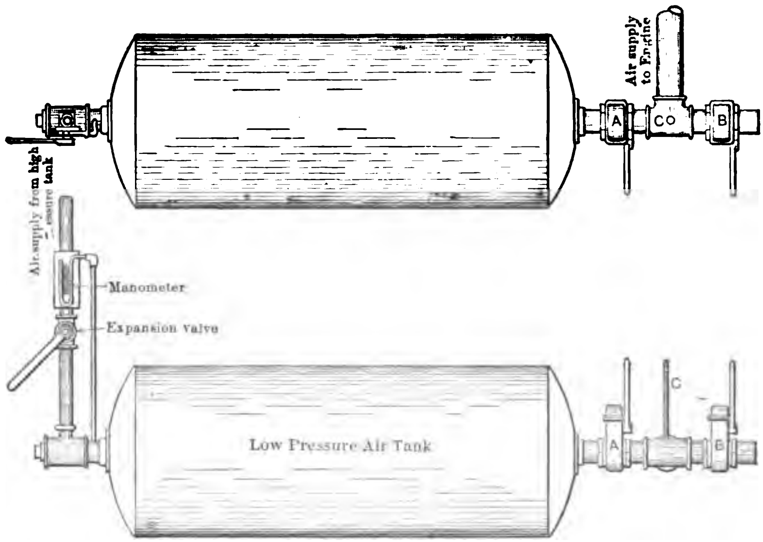
Two pressure gauges were connected to the tank T, one a high-pressure gauge for the start, the other, a low-pressure gauge, for the finish. The latter was used in order to get a more exact determination of the pressure at the stop than could be had with a high-pressure gauge.

The temperatures were obtained by five thermometers inserted in thermometer cups at various heights on the tank. These thermometer cups were of thin copper tubing, and the length (about two feet) such that the bulb of the thermometer was in the middle of the tank. The readings of the thermometers were averaged, and the true temperature of the air ascertained.

9. The arrangement of the low-pressure tank is shown in Fig. 187. The pipe leading from the high-pressure tank is at the left, also the expansion or reducing valve and the manometer. This reducing valve was operated by hand, although some automatic device might be used, and one was tried in these tests, but did not give results as satisfactory as when a man was assigned to this duty.

At the right are two quick-opening valves A and B, through one of which the air must pass in going to the engine. With B open and A closed, the engine will draw air from the atmosphere, while with A open and B closed, the supply will be drawn from the tank.

In starting a test the air is compressed in the storage tank and its temperature and pressure read. At this time the engine is



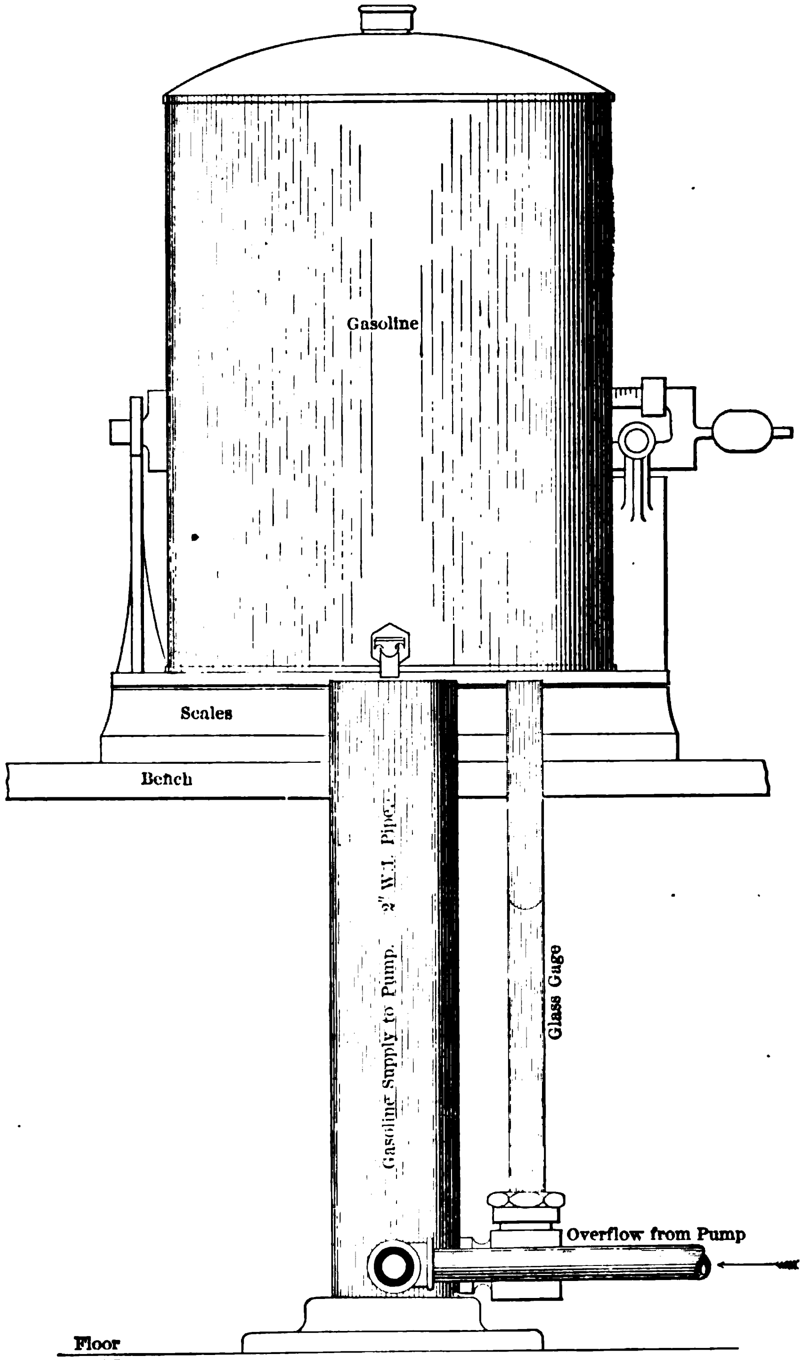
DEVICE FOR SUPPLYING ENGINE WITH WEIGHED AIR.

FIG. 187.

running under the same conditions as will exist during the test. At a given signal the one who operates the reducing valve allows a slight pressure to accumulate in the low-pressure tank, while another person closes B and opens A, simultaneously, so that the engine continues its work without interruption, but now drawing its air supply from the weighed amount. This signal is the start of the test. A thermometer in the intake pipe at C gives the temperature of the ingoing air.

Weight of Fuel.

10. The engine was fitted to use either gas or gasoline, and as the kind of fuel did not enter into the problem, the latter was chosen because it was in a form to be more accurately weighed or meas-



APPARATUS FOR WEIGHING GASOLINE.

Fig. 188.

ured, and a more uniform quality could be insured for any given set of tests.

Common stove gasoline was used, and a sufficient amount set by to supply the engine throughout the tests. A sample was analyzed and its calorific value ascertained.

The apparatus used for measuring the gasoline is shown in Fig. 188. It consists of a tube for holding the gasoline from which the engine supply is pumped : this tube is made of a piece of 2-inch gas pipe, screwed into a floor flange, and plugged at the bottom; near the lower end there are two openings threaded for ½-inch pipe. Into one of these is connected the pipe which leads to the pump, and into the other is screwed a gauge glass fitting such as is used on boilers. A glass gauge indicates the height of the liquid in the main tube. On a bench beside this tube is a platform scale, on which rests the can containing the gasoline, the tap in the bottom of the can opening into the lower tube. The gasoline is protected from the air so that no appreciable evaporation may take place.

When it is about time for starting a test, the tube is filled nearly to the top with gasoline, that remaining in the can is weighed and the amount noted. At the starting signal, the level in the glass gauge is located by a cord tied around the gauge. As the test proceeds, the supply is replenished as necessary, and toward the end of the test the level is brought to the starting point and kept there until the signal to stop is given, when the gasoline is shut off and the can again be weighed. The difference in weight is the net weight of gasoline used.

Heat Rejected to Exhaust.

11. A Wheeler surface condenser was connected to the exhaust pipe of the engine, the same as it would be connected to a steam engine. Thermometers (Fig. 189) were placed in the circulating water pipes so that the temperature could be read before and after passing through the condenser or calorimeter, and the circulating water was weighed. The exact amount of heat abstracted from the exhaust gases could then be calculated.

The temperature of the cooled exhaust gas was measured as it passed away from the calorimeter by a low-range thermometer, *C*. As the gases were reduced considerably in volume, and the velocity through the exhaust pipe further reduced by the muffler action of the condenser, the temperature as indicated by this thermometer was probably nearly correct.

Knowing, then, the final temperature of the exhaust gas, the weight of gas and the total heat abstracted, we may calculate

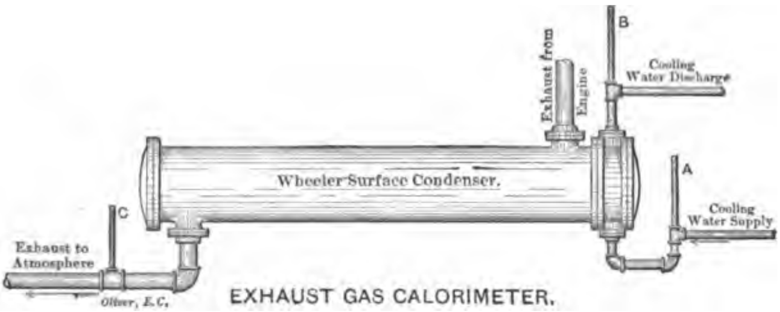


FIG. 189.

the temperature which must have existed in the exhaust gas at atmospheric pressure before the heat was abstracted.

The Heat Absorbed by the Jacket.

12. The heat absorbed by the water-jacket was measured in a manner similar to that of finding the heat rejected in the exhaust, by weighing the water and observing the temperature before and after passing through the jacket.

Duration of Test.

13. The length of test is determined by the capacity of the air storage tank. When getting ready for a test, the pressure in the tank is raised to about 101 pounds, and the valve between the tank and compressor is closed, the gauge is then watched by an observer until it shows just 100 pounds; this decrease in pressure is due to the cooling of the air in the tank. When this pressure is observed, he gives the signal to start, and then reads the temperatures in the tank.

As the test proceeds, the reduction of pressure in the tank requires the observer who controls the reducing valve to open his valve wider and wider to keep up the pressure in the low-pressure reservoir. This continues until the valve is wide open and it is evident that the air supply is about gone; when this occurs he gives a warning signal to the other observers, and watches the manometer until the pressure falls to atmospheric, then gives the signal to stop.

When this signal is given, the observer at the storage tank reads the pressure and temperature as before.

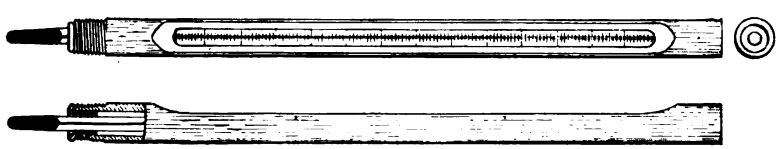
The capacity of the storage tank provided for a test slightly over twenty-two minutes long.

Other Data.

14. The total revolutions and total explosions were determined by means of continuous counters actuated by a part of the mechanism of the engine. The exhaust gas was sampled at intervals throughout the test.

Some difficulty was at first experienced in obtaining a steady flow of water in the water-jacket and exhaust calorimeter, as the supply was from the city water pipes, and any valves opened on the line would change the flow at the engine slightly. This was obviated by placing a tank over the engine having a pipe in the bottom connected to the jacket and calorimeter, and an overflow which would prevent the water rising above a definite level. The supply from the city water was piped into this tank and was so regulated that there was always a slight overflow from the waste pipe which was visible. Thus any variations in the water pipes had no effect on the supply to the engine.

Wherever thermometers were used, if not under pressure, the bulb was in direct contact with the water or gas, and the stem



Otter, E.C.

THERMOMETER GUARD.

FIG. 190.

was protected by a shield as shown in Fig. 190. These shields were made of $\frac{3}{8}$-inch gas pipe, with an opening milled on the side. The lower end was threaded to standard gas pipe size on the outside, and the inside reamed smooth with a taper reamer. The joint between the thermometer and the pipe was made with a piece of rubber tubing. They were easy to insert, and remove, and saved much of the annoyance and expense due to breakage.

Data from Test.

15. From one of the several tests which were run on this engine the data collected were as follows :

Engine cylinder, bore 5¾ inches, stroke 12½ inches.
Clearance, 107 cubic inches.
Duration of test, 22½ minutes.
Brake load, 30 pounds.
Revolutions per minute average, 299.6.
Total number of explosions, 3,332.
Weight of gasoline used, 2.43 pounds.
Weight of jacket water, 361 pounds.
Rise in temperature of jacket water, 47.4 degrees Fahr.
Weight of exhaust cooling water, 382 pounds.
Rise in temperature of exhaust cooling water, 37 degrees Fahr.
Air pressure in tank at start, 100 pounds gauge.
Air temperature in tank at start, 96.8 degrees Fahr.
Air pressure in tank at stop, 1 pound gauge.
Air temperature in tank at stop, 78.8 degrees Fahr.
Volume of storage tank, 89.6 cubic feet.
Temperature of air entering engine, 70 degrees Fahr.
Temperature of exhaust gas leaving cooler, 102 degrees Fahr.
Scale of spring in power indicator, 240 pounds.
Scale of spring in pumping indicator, 60 pounds.

Analysis of gasoline.

Carbon	.838
Hydrogen	.155
Impurities	.007
	1.000

Heating value per pound, 18,281 British thermal units.
Density—71 degrees Baumé.

Analysis of burned gas.

CO_2	.0926
O	.0338
H_2O	.0751
N	.7985
C. O.	.0000
	1.0000

Results of Test.

16. The results of one of these tests with some of the calculations have already been published in the *American Machinist* of June 26 and July 10, 1902, and need only be referred to here. It may be convenient, however, to add the principal results and the computation for obtaining the temperature of the exhaust gas at atmospheric pressure, as the latter might be submitted as a satisfactory way of ascertaining a temperature which is generally considered as desirable, and yet for which no convenient and at the same time accurate method of determination has been proposed.

17. The results are embodied in a heat balance which follows, and a temperature volume curve, Fig. 191:

HEAT BALANCE FOR OTTO GASOLINE ENGINE.

	Dr.	Cr.
	B. T. U.	B. T. U.
2.43 lbs. gasoline at 18281 B. T. U..........	44423	
9.988 Brake horse-power..............	....	8483
1.762 Friction horse-power..............	....	1663
361 lbs. Jacket water at 47.4 deg. Fahr......	....	17111
382 lbs. exhaust cooling water at 37 deg. Fahr. = 14134		
Heat remaining in exhaust...... 371	....	14505
		41762
Radiation and other losses................	....	2661
	44423	44423

Stated in percentages, this heat balance will appear as follows: Heat supplied, 100 per cent.

Brake horse-power....................................	19.1
Friction horse-power....................................	3.7
Jacket water....................................	38 5
Exhaust....................................	32.7
Radiation....................................	6.
	100.0

18. The thermal efficiency of the engine will be the sum of the first and second entries, or the heat equivalent of the indicated horse-power, divided by the total heat supplied :

$$19.1 + 3.7 = 22.8 \text{ per cent. thermal efficiency.}$$

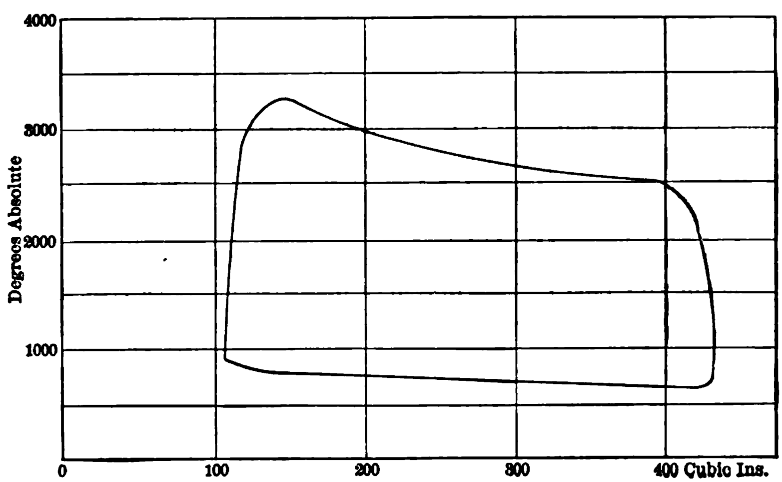
TEMPERATURE OF THE EXHAUST GAS AT ATMOSPHERIC PRESSURE.

Total weight of exhaust gas expelled.............	45.1 pounds.
Temperature of exhaust gas expelled............	102 deg. Fahr.
Total heat abstracted by cooling exhaust	14,134 B. T. U.
Specific heat at constant pressure	.2573
Water of combustion, liquified....................	3.39 pounds.

The last item was determined from the known weight of hydrogen contained in gasoline.

If now the process of cooling the exhaust gas be reversed, we must necessarily arrive at the temperature that must have existed after expansion to atmospheric pressure.

19. Before heating the gas, the water of combustion must be heated to 212 degrees and evaporated. This process will require



Oliver, E.C. TEMPERATURE VOLUME DIAGRAM FOR A GASOLINE ENGINE.

FIG. 191.

111 British thermal units per pound to heat, 965.7 British thermal units per pound to evaporate, and therefore the heat units available for heating the body of the gas will be

$$14{,}135 - 3.39\,(965.7 + 111) = 10{,}484 \text{ B. T. U.}$$

As the total weight of gas is 45.1 pounds, this will allow $\frac{10484}{45.1} = 232.5$ B. T. U. per pound of gas.

With a specific heat of 0.2573 this amount of heat will produce a rise of temperature of $\frac{232.5}{0.2573} = 904$ degrees.

This added to the initial temperature, 102 degrees Fahr., equals 1,006 degrees Fahr. as the temperature of the exhaust gas at atmospheric pressure, which in absolute degrees is 1,467.

20. Many tests have been run on this engine with the apparatus as described, which seemed to give data more accurate than could be secured by the usual methods, but there are still many improvements which might be made in the methods to secure still greater exactness. The apparatus, if it were necessary to collect it for a single test, would prove rather expensive and cumbersome, but in places where tests of this character are performed, there is usuallly sufficient apparatus which can be adapted to the requirements, and this was so in the present case. No special outlay was required outside of the purchase of a few fittings and the expense of fitting up.

There has been omitted so far one tactor which is by no means the least important in a test of this kind. One has only to attempt work of this character to realize his dependence on the observers who are required to collect the data. The many readings and operations that must take place simultaneously and with certainty, especially at the start and stop of a test, make careful training of the observers of the greatest importance, as the least error on the part of any one may make the test worthless. It is not every starting signal that means a test.

No. 990.*

PERFORMANCE OF AN INTERNAL COMBUSTION ENGINE USING KEROSENE AND GASOLINE AS FUEL.

BY H. F. HALLADAY, POTSDAM, N. Y.
(Junior Member of the Society),
AND
G. O. HODGE, POTSDAM, N. Y.
(Non-member).

1. This paper is the outgrowth of a series of investigations made in the mechanical engineering laboratory of the Thomas S. Clarkson Memorial School of Technology. Their object was to determine the economic performance of a standard internal combustion engine of the Otto type using kerosene and gasoline, respectively, as fuel under otherwise similar conditions. Apart from the mere question of cost of the fuel there were several interesting phenomena observed and operating characteristics determined for each case.

There is necessarily a fixed brake horse-power limit for each kind of fuel used in an internal combustion engine. The engine tested was nominally rated to deliver 15 horse-power at 260 revolutions per minute. Under test the maximum limit of power delivery was by gasoline, 14.91 horse-power at 267.4 revolutions; and, for kerosene, 17.41 horse-power at 309 revolutions. That is to say, this engine was found to be capable of developing 16.8 per cent. more power with kerosene than with gasoline for the samples of these two fuels of chemical composition and heating value as determined, and recorded in Table IV.

2. Accompanying the increased capacity of the engine with kerosene it was also found that it could be operated with this fuel at better efficiency and fuel economy at all loads above about 40 per cent. of the normal full load. The cost of the fuel when the

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

tests were made was $0.14 per gallon for kerosene and $0.145 for gasoline. The heating values of the fuels by Mahler bomb calorimeter tests were 19,282 British thermal units per pound for the kerosene and 20,296 British thermal units for the gasoline, averages from four tests each, Table IV.

The tests with gasoline were made with the apparatus as supplied by the builders when purchased. The tests with kerosene required special attachments, adjustments, and methods which it is one of the objects of this paper to describe. A great deal of experimenting was necessary before the engine could be successfully operated with kerosene, but the work was finally carried out with entire success.

Description of the Apparatus.

3. The engine used was of the standard horizontal four-cycle type made by the Otto Gas Engine Co., Philadelphia, Pa. The governing is effected by the "hit and miss" method. It may be operated with gas or gasoline as fuel. The change from one to the other is readily made by simple adjustments of two valves. But the regular gasoline valves supplied by the engine were used throughout all of these tests when both kerosene and gasoline were employed as fuels. The general arrangement is shown in Fig. 196.

The Cooling Jacket.

4. The cylinder walls were kept cool by the usual water jacket. The water was taken from the city mains, passed through the jacket and emptied into a tank on platform scales for weighing. Thermometer wells filled with oil were screwed into the water pipes near the entrance to and exit from the jacket, at points *a* and *b*, respectively, Fig. 195. The temperatures of the cooling water were regularly noted at these points.

The Absorption Brake.

5. The belt pulley of the engine was converted into a suitable brake pulley, Fig. 192, by fastening to its rim internal flanges about four inches deep. These flanges formed an annular trough for holding the cooling water for the brake. The water was delivered to and taken from this pulley by the usual piping system. The brake was calibrated and the weighings were taken by platform

scales. The brake arm was made 63.025 inches long, being so proportioned as to reduce the calculations required by obtaining the revolution constant for the regular brake horse-power formula.

The Carburetor for Kerosene.

6. In order to use in the engine kerosene oil it must be sprayed into a heated chamber, where it is vaporized and the vapor super-

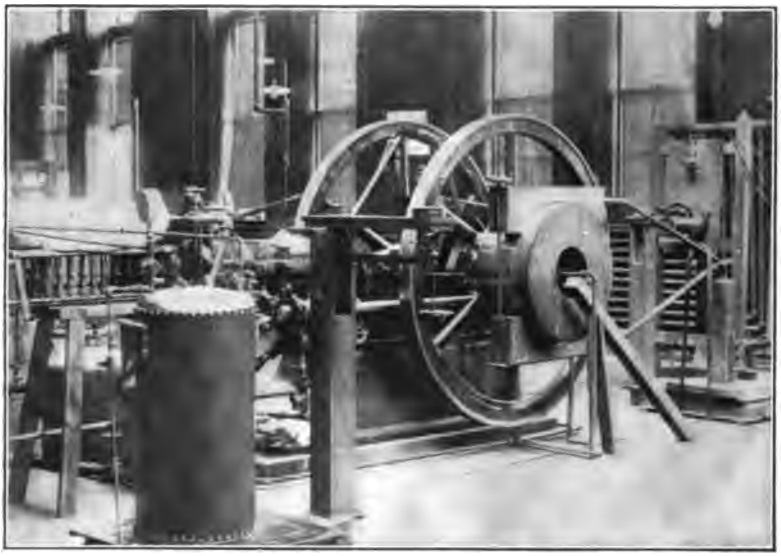


FIG. 192.

heated. By an internal air jet the kerosene may be broken up into a fine spray or mist which at the same time may serve to carburize the air used to atomize the oil. The kerosene-air mixture must then be thoroughly vaporized by an external source of heat. It is further necessary to superheat this mixture sufficiently to prevent condensation of the vaporized oil upon its entering the cooler gas ports and passages of the engine.

Special attachments to effect the above changes in the kerosene were designed by the authors and constructed in the shops of the Clarkson School of Technology. Fig. 192 shows the engine arranged for testing with kerosene as fuel. Attached to the cylinder is the superheating and vaporizing chamber shown in general view, Fig. 193. At the outer end of this chamber is the atomizer with needle throttle valve, shown in detail, Fig. 194.

7. The atomizing arrangement consists of a small brass cylinder, four inches long, fitted with two needle valves, 2 and 3, Fig. 194. These control respectively the flow of kerosene oil and the supply of compressed air from pipes *a* and *b*. The spindles of the needle valves were fitted with pointer and graduated index plates for mutual adjustment of compressed air and kerosene oil to the

FIG. 193.

desired degree of refinement, without loss in quantity of oil or change in its chemical composition.

The compressed air, entering through pipe *b*, passes through the fine perforations in needle valve 2, thence through its very small bore *x*, emerging from which it sprays the kerosene oil supplied through pipe *a*. The result is the formation at the conical orifice, *c*, of an exceedingly fine spray of kerosene-air mixture which thence enters the vaporizer.

8. The vaporizer and superheater consists of a closed wrought-iron pipe, 2 feet long and 5 feet inches diameter. It is heated by a number of Bunsen burners placed beneath, and heat insulated and protected from drafts by asbestos sheets. The temperature of the superheated kerosene-air mixture was continuously ob-

served. It was kept on the average within the range of 590 to 670 degrees Fahr. At a lower temperature than 575 degrees Fahr. the vapor would be at once condensed in the colder admission parts and passages of the engine. The temperature of vaporization of the kerosene oil was about 380 degrees Fahr., so that the degree of superheat was on the average about 240 degrees Fahr.

Weighing Tanks for the Fuel.

9. The kerosene was supplied from a suitable tank on platform scales as shown in Fig. 192. To force the oil through the atomizer an air pressure of from 30-40 pounds per square inch was maintained in the tank. The compressed air was furnished by a small

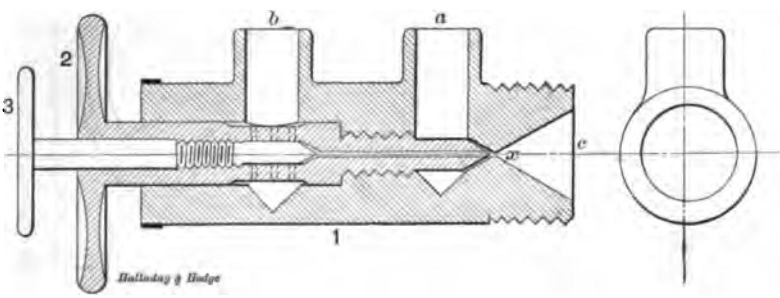


FIG. 194.

air pump operated from an overhead shaft driven by an independent source of power.

The kerosene tank was connected with the atomizer by two pipes, Fig. 192. One pipe from the top of the tank furnished the compressed air necessary to spray the kerosene conveyed under pressure by the other pipe.

The gasoline was supplied from a 5-gallon tank placed on small platform scales. Two pipes connected this tank, respectively with a supply tank outside the engine room and with the regular gasoline nipple of the engine.

Very small wrought-iron pipes of considerable length were used for each of the above tank connections. It was found by experiment that they did not support the tank nor interfere with the weighings of the fuel. The accuracy of the arrangement was tested by trial with known weights, and it was found possible to weigh to one-quarter of an ounce.

Kerosene used as a Power Gas.

10. The kerosene fuel was supplied to the engine as a kerosene-air mixture, superheated from about 590 to 670 degrees Fahr. The engine was therefore operated under conditions somewhat similar to the use of blast furnace and waste power gases as fuel. Several of the results are in the line of what may be expected from the use of such highly superheated gas-air mixtures in internal combustion engines. With these gases there is of necessity more or less of an admixture of air before introduction into the

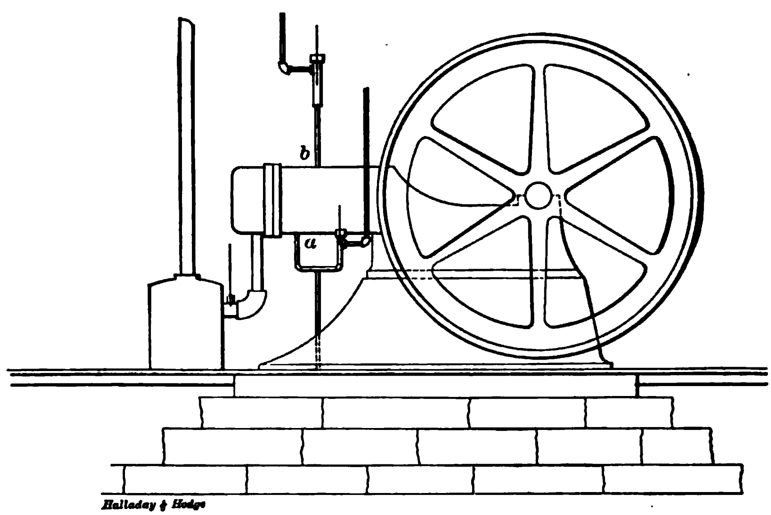


FIG. 195.

engine cylinder. There the fuel is further mixed with air for finally effecting a suitable explosive mixture according to the loads to be met.

With the superheated kerosene-air mixture there is very quick explosion. It is evident from the pounding noticeable in the engine, which could not be attributed to any other cause, such as pre-ignitions, or too high a temperature of the working gas, or soot on cylinder walls. This pounding could not be done away with except by changing the point of ignition, and such a change would be at the expense of the efficiency. A comparison of the explosive nature of the kerosene and gasoline gases may be seen from the indicator cards. Card No. 11, test No. 8, of the kerosene series, shows a maximum pressure of 404 pounds, and card

No. 7, of test No. 3, of the gasoline series shows a maximum pressure of 309 pounds, while the mean effective pressures are almost the same, 85.65 and 86.40 pounds respectively.

Adjustments and Methods of Testing with Kerosene Fuel.

11. The series of tests were run under practically constant speed and as constant load as could be maintained under the conditions imposed by the variable adjustments of fuel, air, and cooling water required for maximum efficiency. In each run with kerosene the proportions of air and fuel and the amount of jacket water were found to be properly adjusted when the speed was so regulated mutually with the load as to give conditions which insured most efficient performance.

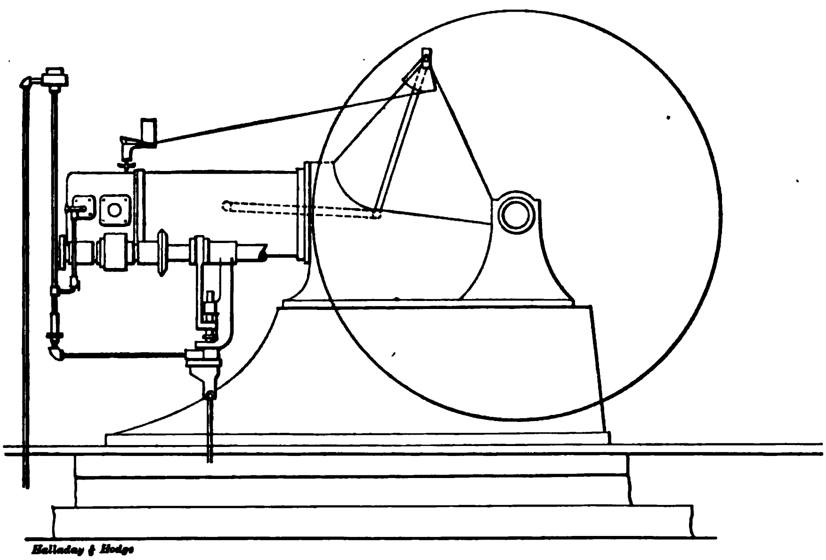


FIG. 196.

The proper proportions for the kerosene-air mixture were determined for each series of tests to be run under constant speed and load, as follows:

12. The air supply was throttled till no appreciable smoke was visible in the discharge from exhaust pipe. At such a time the analyses of exhaust gases, as fixing one of the best conditions for maximum efficiency, should show an excess of oxygen and a mini-

mum amount of carbon monoxide. The analyses of the exhaust gases were obtained with an Orsat apparatus.

The jacket was maintained at as high a temperature as permissible. This is the other necessary condition for best efficiency. It was the condition sought in all of the high-power tests throughout the range of loads for the most efficient performance. The jacket temperature, however, should not exceed the limit prescribed for satisfactory lubrication and mechanical operation of the engine. The mechanical friction of the engine is largely influenced by the temperature of the cylinder walls as determined by the cooling water in jacket.

The load on the brake arm was adjusted in order to determine, within the allowable range, the proper speed for obtaining the maximum horse-power under the given conditions. The total ranges of speed included by the several tests were, for kerosene, 244-309 revolutions per minute; and, for gasoline, 236-275 revolutions. Throughout a small range at normal loads it was found, on reducing the above scale weight, that the speed increased to a larger extent than would be required to meet the simple reduction under a constant load. For the brake horse-power was calculated from a speed constant multiplied by the scale weight in pounds.

The speed adjustments for each set of conditions would result in the speed finally settling to a value representing a slightly increased brake horse-power as the effect of reducing, for instance, the weight on the brake scales. The speed was then maintained practically constant throughout the run under the conditions imposed upon the engine by the loads assigned. In the series with kerosene, the regular "hit and miss" governing device of the engine was not used.

Conduct of the Experiments.

13. The same general plan for conducting the experiments was followed with the kerosene and gasoline fuels except as elsewhere specially described for kerosene.

Duration of Runs.—With kerosene there were ten runs—two of them of thirty minutes duration (one under very light load), five of one hour, and three of ninety-minutes' duration. With gasoline there were eight runs—one of them for the friction horse-power of thirty-minutes' duration, six of one hour, and one of ninety-minutes' duration. All calculations of power, fuel con-

consumption, and heat distribution have been reduced to the hour basis.

Readings.—Readings were taken at five-minute intervals throughout the series of observations of which the averages are given in the summary of tests, Tables V. and VI.

Speed.—The revolutions of the engine were recorded by a Veeder continuous counter.

Explosions.—The number of explosions per minute was found by actual count in each case. In the gasoline tests, throughout the range of normal full loads, the governor was fixed in such a position that explosions occurred every two revolutions. In the kerosene tests, the regular governing device was disconnected, and the regulation effected by throttling both the air and kerosene mixture. In this case the explosions were determined directly from the number of revolutions of the engine, except under very small loads when actual count was necessary. Card No. 1, Fig. 197, gives an example of a failure to get an explosion under light loads with kerosene fuel.

Indicator Cards.—There were taken at five-minute intervals by a special Crosby gas-engine indicator. The area of its piston was one-half that of the standard Crosby steam-engine indicator.

Temperatures.—These were taken at the same regular intervals and at the points of observation elsewhere noted in diagrams and tables. The exhaust temperatures were taken by a special, high-reading mercurial thermometer made of "Jena normal glass," graduated from 180 to 550 degrees Centigrade. It was placed in asbestos in a special brass thermometer well tapped into the exhaust pipe near the exhaust valve.

With gasoline the average exhaust temperatures for each series agreed as closely as could be expected. The comparatively low temperature of 788 degrees Fahrenheit for one of the heavy loads was due to starting the test and taking readings before the engine was fully warmed up. There seemed to be no fluctuation of the exhaust temperatures, even under light loads, when there was more or less reduction in the number of explosions per minute.

Heating Value of the Fuels.

14. The heating values were all obtained with the Mahler Bomb Calorimeter. The fuels being exceedingly volatile under high temperatures, it was necessary to use small glass bulbs filled and

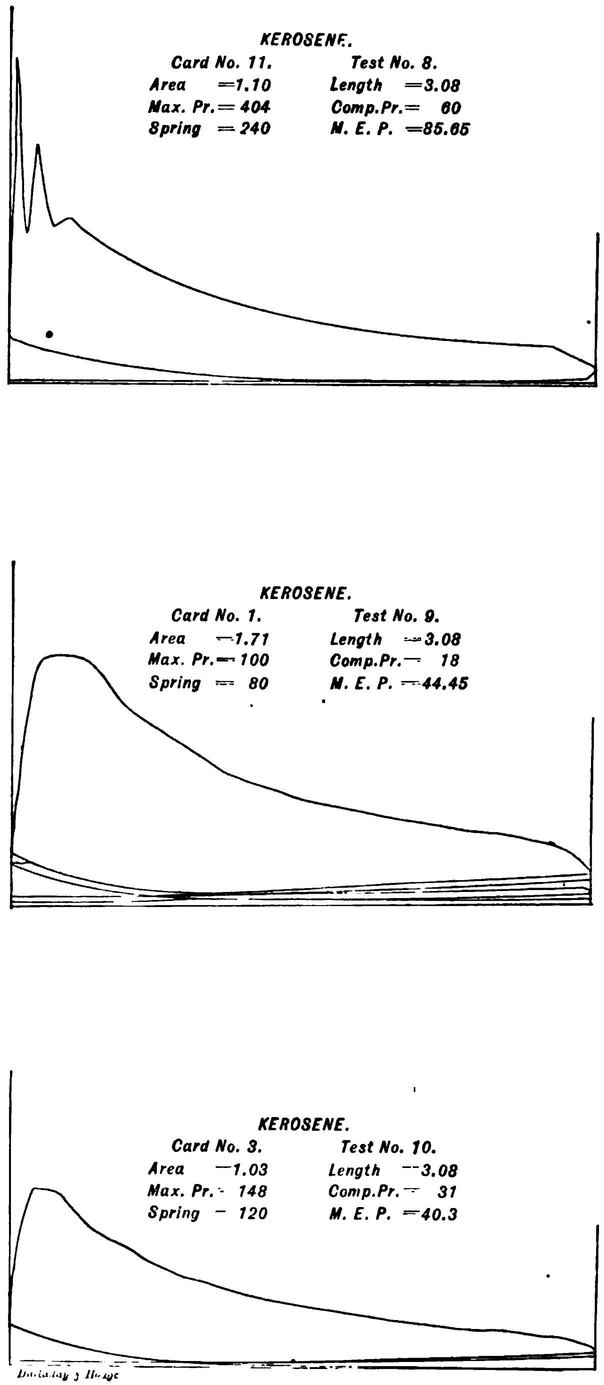

KEROSENE.
Card No. 11.
Test No. 8.
Area =1.10
Length =3.08
Max. Pr. = 404
Comp.Pr. = 60
Spring = 240
M. E. P. =85.65
KEROSENE.
Card No. 1.
Test No. 9.
Area =1.71
Length =3.08
Max. Pr. = 100
Comp.Pr. = 18
Spring = 80
M. E. P. =44.45
KEROSENE.
Card No. 3.
Test No. 10.
Area =1.03
Length =3.08
Max. Pr. = 148
Comp.Pr. = 31
Spring = 120
M. E. P. =40.3

FIG. 197.

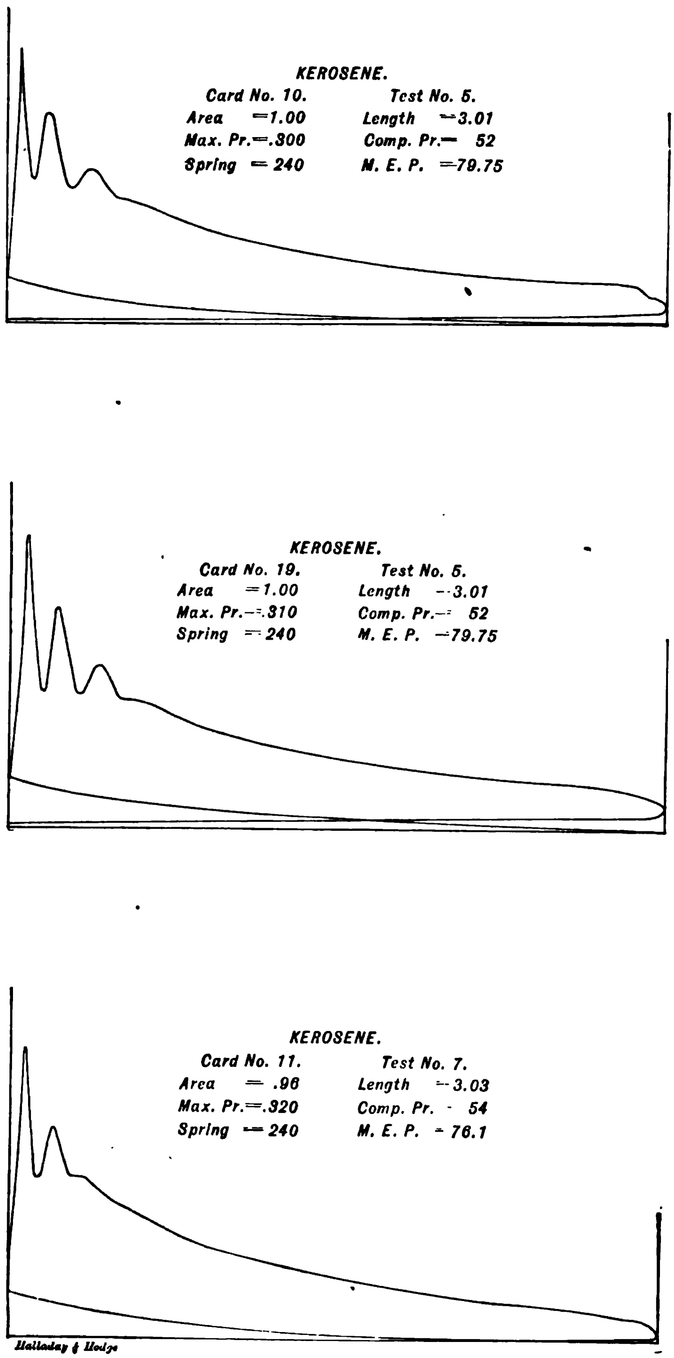

KEROSENE.
Card No. 10.
Test No. 5.
Area =1.00
Length =3.01
Max. Pr.=.300
Comp. Pr.= 52
Spring = 240
M. E. P. =79.75
KEROSENE.
Card No. 19.
Test No. 5.
Area =1.00
Length =3.01
Max. Pr.=.310
Comp. Pr.= 52
Spring = 240
M. E. P. =79.75
KEROSENE.
Card No. 11.
Test No. 7.
Area = .96
Length =3.03
Max. Pr.=.320
Comp. Pr. = 54
Spring = 240
M. E. P. = 76.1
Halladay & Hodge

FIG. 198.

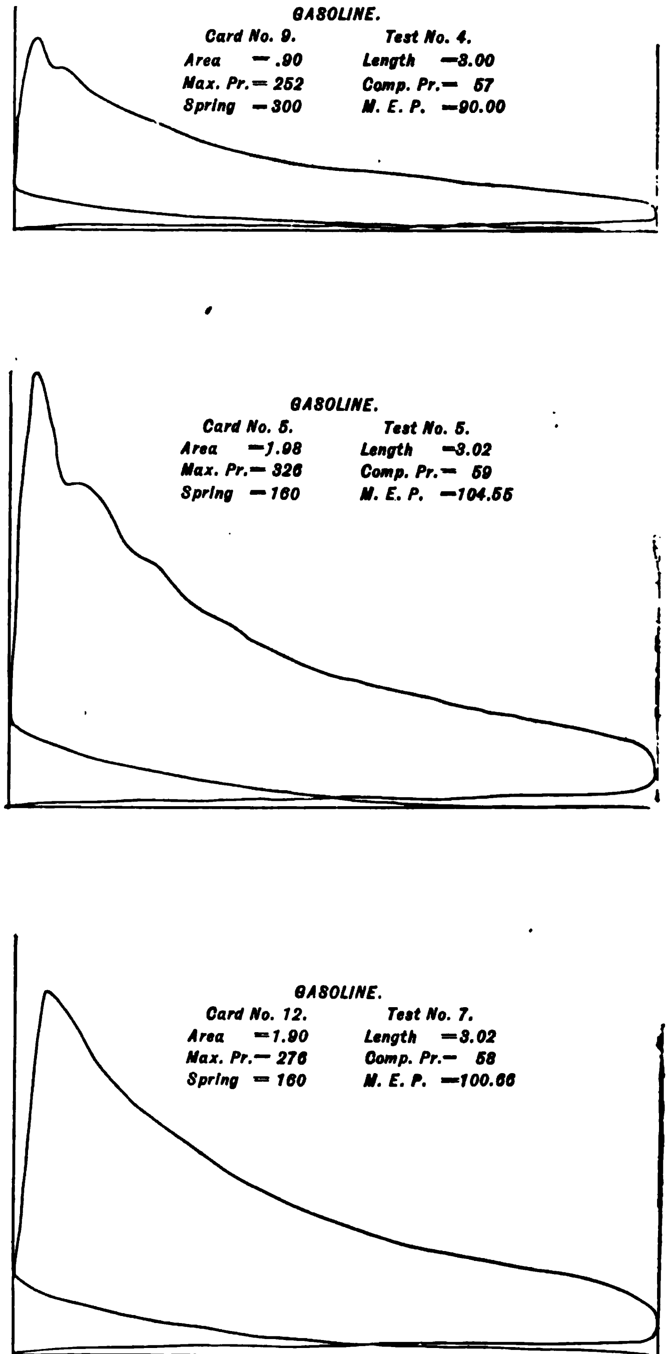

GASOLINE.
Card No. 9. Test No. 4.
Area —.90 Length —3.00
Max. Pr.=252 Comp. Pr.— 57
Spring —300 M. E. P. —90.00
GASOLINE.
Card No. 5. Test No. 5.
Area —1.98 Length —3.02
Max. Pr.— 326 Comp. Pr.— 59
Spring —160 M. E. P. —104.55
GASOLINE.
Card No. 12. Test No. 7.
Area =1.90 Length =3.02
Max. Pr.— 276 Comp. Pr.— 58
Spring = 160 M. E. P. —100.66

FIG. 199.

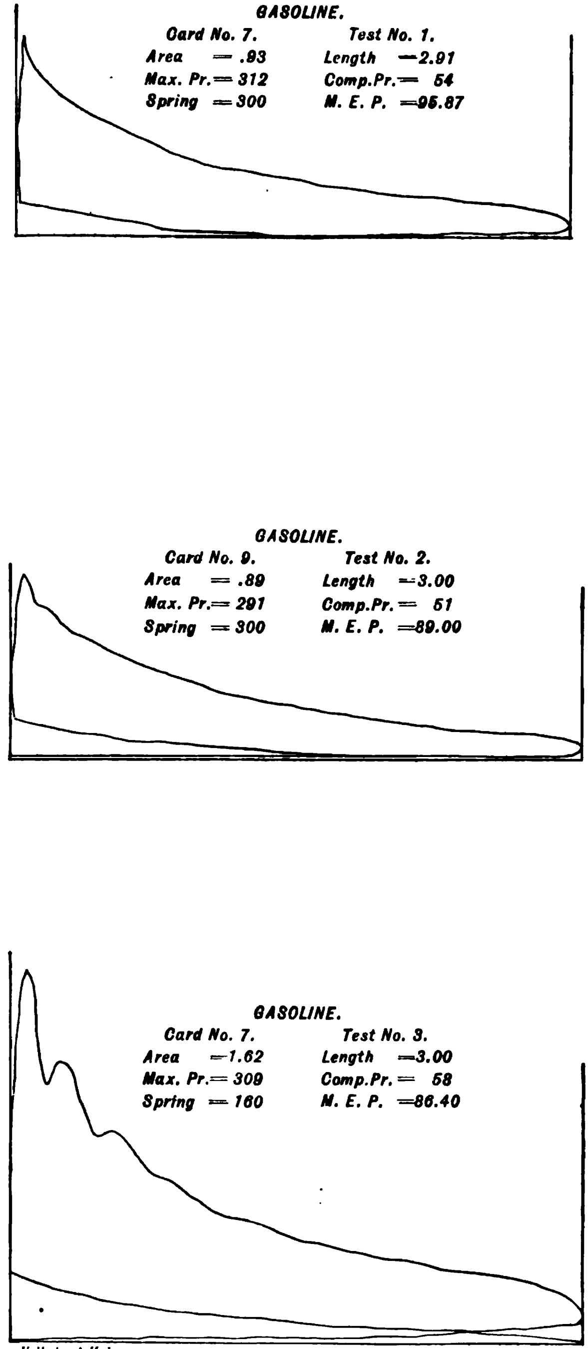

GASOLINE.
Card No. 7. Test No. 1.
Area = .93 Length = 2.91
Max. Pr. = 312 Comp. Pr. = 54
Spring = 300 M. E. P. = 95.87
GASOLINE.
Card No. 9. Test No. 2.
Area = .89 Length = 3.00
Max. Pr. = 291 Comp. Pr. = 51
Spring = 300 M. E. P. = 89.00
GASOLINE.
Card No. 7. Test No. 3.
Area = 1.62 Length = 3.00
Max. Pr. = 309 Comp. Pr. = 58
Spring = 160 M. E. P. = 86.40
Halladay & Hodge

FIG. 200.

sealed. The weight of sample contained in each bulb was found by weighing the bulb before and after filling. One of these bulbs was placed in the calorimeter and oxygen under a pressure of five atmospheres was admitted, and the bomb then shaken until the bulb was broken, thus giving a combustible mixture. This was ignited by an incandescent wire and the heating value of the sample obtained, as indicated by the accompanying test sheets.

After the pressure in the bomb had been relieved and the cap removed, the bomb was thoroughly washed with distilled water and the nitric acid (HNO_3) was found. The sulphur was precipitated as barium sulphate, thus giving the sulphur as shown on the accompanying test sheets.

The kerosene and gasoline used were drawn entirely from individual barrels, thus obtaining good samples. A series of tests of these samples gave average heating values and chemical composition.

From the chemical analysis of the gasoline the per cent. of hydrogen was found to be 14.14. The produced water will, therefore, be 1.2726 times the weight of gasoline used, 14.14 x 09 = 1.2726. Taking the latent heat of vaporization of water at 20 degrees Centigrade as 592.5 gives 0.754 calories per gram; deducting this from the average calorific value of the gasoline of 11,276, gives 10,522 as the heat of combustion of one gram of gasoline, which is equivalent to 18,940 British thermal units per pound of gasoline.

Chemical Analysis of the Fuels.

15. This was exceedingly difficult to obtain because of the higher hydrocarbons, which it was found were not readily burned. It was made with an ordinary combustion furnace. The hard glass tube in which the combustion is made should be carefully selected and preferably drawn out at one end into a tube about two and one-half inches long by one-fourth inch in diameter, this end being placed toward the collectors. The tube used was thirty inches long by five-eighth or three-quarters inches in diameter. It was charged with copper gauze thoroughly oxidized and with black copper oxide.

A straight tube stoppered at both ends with rubber stoppers containing glass tubes was used. This was charged as before, the copper oxide being relied upon to furnish oxygen enough for complete combustion. After several trials with varying results, it was found that the oxide would not give up its oxygen rapidly enough nor in sufficient quantity to thoroughly oxidize the hydrocarbons. To remedy this defect, or rather to supply the lack of oxygen, it was supplied very slowly from a cylinder. Analyses employing this method were quite satisfactory.

16. In the case of gasoline, for instance, the carbon found was 83.53 per cent., the hydrogen, 14.14 per cent. Using Dulong's formula for heating value of a hydrocarbon, we obtain 20,947 British thermal units, this being but slightly different from the result obtained in the calorimeter, 20,296 British thermal units; thus,

$$.8353 \times 14{,}500 + .1414 \times 62{,}500 = 20{,}947 \text{ B. T. U.}$$

From the chemical analysis of the kerosene the per cent. of carbon and hydrogen were respectively 84.13 and 13.87 per cent. Using the above formula, the following heating value was obtained:

$$0.8413 \times 14{,}500 + 0.1387 \times 62{,}500 = 20{,}869 \text{ B. T. U.}$$

The apparatus used was the combustion furnace with the tube as described and charged, with a small U tube for collecting the water, there being a bulb in which the water could condense. Just enough sulphuric acid (H_2SO_4), sp. gr. 1.90, was put into the tube, so that all the gas going through the tube would pass through the acid. This was found to be a better drying or water-collecting agent than fused calcium chlorid, and would pick up the water if the rate of passing did not exceed two bubbles per second. It is better to run much slower than this.

17. The bulb filled with a solution of caustic potash (KOH), 30 per cent. by weight, with a calcium chlorid guard tube attached, was used for absorbing the carbon dioxide. This tube should be refilled after each combustion. A tube containing fused caustic potash was connected to this as a safeguard. A suction pipe was worked through a bottle of sulphuric acid in order to prevent any moisture in the air from being taken up by the caustic potash tube. The oxygen cylinder and air supply were connected to the other end of the combustion tube and each supply was drawn through caustic potash and fused calcium chlorid in order to free them from carbon dioxide and moisture.

The tube, having been charged, is connected up with the air supply on the one end and a tube of fused calcium chlorid on the other, the heat is then applied gradually until the tube has reached a cherry-red heat; here it is maintained throughout the combustion. About ten inches of the end toward the oxygen supply is left clear. Into this clear space is put the bulb containing the sample, having first broken the tip. This is allowed to expand for a short time, then the oxygen is turned on at the rate of about forty bubbles per minute; if the rate be much faster it will cause an explosion in the tube and ruin the analysis.

18. This is continued until all of the sample is driven out of the bulb and vaporized; the time was usually one and one-half hours. Heat is then slowly applied to the end of the tube containing the bulb. When all the sample is burned, the oxygen is turned on more rapidly and allowed to flow until the copper is oxidized. This can readily be ascertained by the rate of passage of the bubbles through the sulphuric acid. When the copper has taken up all the oxygen which it can, the suction is turned on and air drawn through for fifteen minutes; this should take over all the condensed water; if it does not, continue until it has removed all signs of moisture in the combustion tube. The absorbent tubes are now carefully removed and a new set attached for another combustion. It is better to run a number in succession than to stop with one. The tubes when cool should be carefully weighed.

Gasoline Analysis.

Sample No. 1.	Test No. 8.	
Weight of bulb empty............................		grams.
" " " filled..............................		"
" " gasoline..............................	.3624	
Weight of H_2SO_4 tube before combustion............	83.1856	"
" " " " after "	83.6470	"
Increase..	.4614	"

$$.4614 \div 9 = .05127 \text{ grams hydrogen.}$$
$$.05127 \div .3624 = 14.14 \text{ per cent.}$$

Weight of KOH bulb before combustion.............	60.4990	"
" " " " after "	61.6090	"
Increase..	1.1100	"

$$1.11 \times \frac{3}{11} = .3027 \text{ grams of carbon.}$$
$$.3027 \div .3624 = 83.53 \text{ per cent.}$$

Increase on KOH tube............................	0.00	"

Sulphur Determination in Gasoline Used.

From the amount of H_2SO_4 found is .... 0.0027 grams.

$$H_2 = 2 \therefore \frac{32}{98} \times .0027 = .00088,$$

$$S = 32 \quad \text{or} \quad .088 \text{ per cent.,}$$

$$O_4 = \frac{64}{98} \text{ sulphur.}$$

Nitrogen Determination in Gasoline Used.

No. of sample.	Amount of sample used.	$\frac{n}{10}$ N·OH	B$_a$SO$_4$	H_2SO_4
2	0.5895	5.7	.004	
3	0 3861	6.3		
4	0.4261	8.3	.0021	
	3/1.4017	3/20.3	2/.0061	
	4672	6.7	.0030	

Averages placed on a one-gram basis:

1	14.3	.0064

$$0.0064 \times 0.42006 = .0027 \; H_2SO_4.$$

$$\text{Due cc } N_aOH \frac{n}{10} = .0049 \; H_2SO_4.$$

$$\therefore 0.0027 + 0.0049 = 0.54 \quad N_aOH\frac{n}{10}.$$

$$0.0063\,(14.3 - 0.54) = .087 \quad HNO_3.$$

$$H = 1 \therefore \frac{14}{63} \times 0.087 = 0.0193 \text{ G. N.}$$

$$N = 14.$$

$$O_3 = \frac{48}{63} 0.0193 + 100 = 1.93\% \text{ N.}$$

Fuel Consumption.

19. The fuel consumption per brake and per indicated horse-power per hour are shown in Figs. 201, 202, and 203. The minimum consumption or best economic load of the engine occurs at 8.1 brake horse-power for kerosene and at 9.5 brake horse-power for gasoline; that is, for kerosene at about 46 per cent. of the maximum full load for that fuel, and for gasoline at 63.6 per cent. of the maximum full load for this fuel. Under very light loads the gasoline is the more economic fuel, as noted by the intersection of the economy curves, Fig. 203, at about 4.5 brake horse-power.

The kerosene proved to be the better fuel for heavy loads in the given engine, not only in point of economy but also in matter of speed, as elsewhere noted under adjustments and methods with this fuel.

Mechanical Friction and Efficiency.

20. The mechanical friction of the engine represents a double transformation: first, a conversion of heat into internal work and

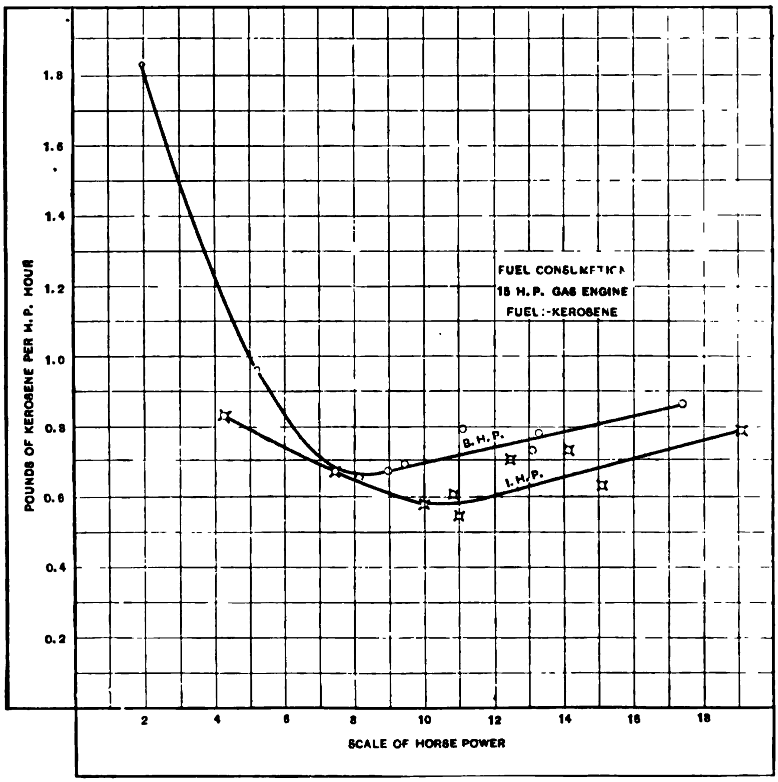


FIG. 201.

other lost work of the engine; thence, a reconversion of this energy into heat by friction. It is therefore subject to more frequent and uncertain variations in gas than in steam engines. In the latter it has been repeatedly shown to follow closely the law of constant friction horse-power for all loads at uniform speeds. In the gas engine there are additional variations in friction loss due to the inherent difficulties of lubrication, as well as the marked influence of the cooling jacket, which has been elsewhere explained under that caption.

21. The friction horse-powers are shown plotted in Figs. 204 and 205, respectively, for kerosene and gasoline. They vary somewhat irregularly. The results with each fuel show a general tendency of the aggregate frictional losses to decrease continuously as the load on the engine increases. The performance of

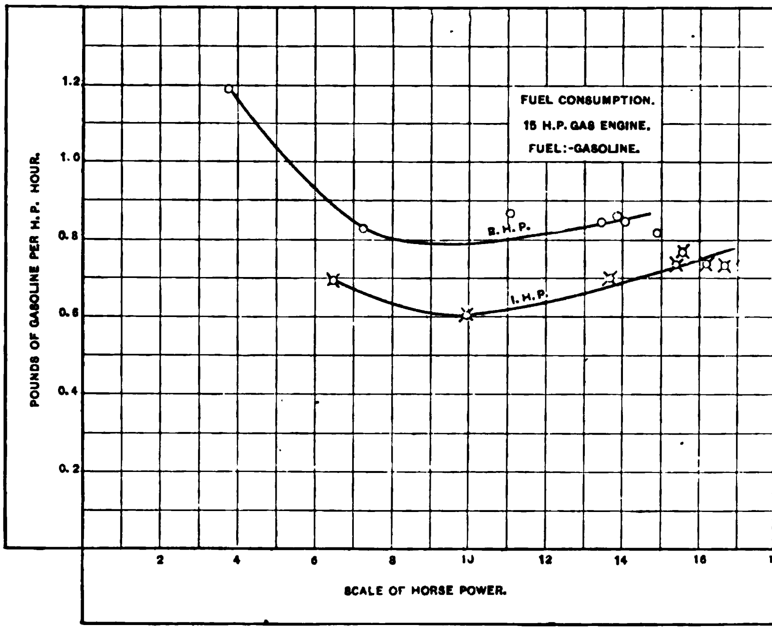


FIG. 202.

the engine as a mechanism, therefore, shows a more rapid increase of mechanical efficiency with increasing load than would be seen if the friction loss were constant.

With kerosene the engine appeared to work much better at a speed above the normal. Thus, Test No. 8 shows an average speed of 309 revolutions per minute with a mechanical efficiency of 91.5 per cent., developing the largest output ever obtained from the engine, of 17.41 brake horse-power. Corresponding conditions for gasoline were at a speed of 267.4 revolutions, mechanical efficiency of 89 per cent., and maximum of 14.91 brake horse-power.

Heat Distribution.

22. One object of this investigation was to ascertain the distribution of the total heat supplied by the fuel as far as could be determined for the following stages of the cycle: the cooling jacket,

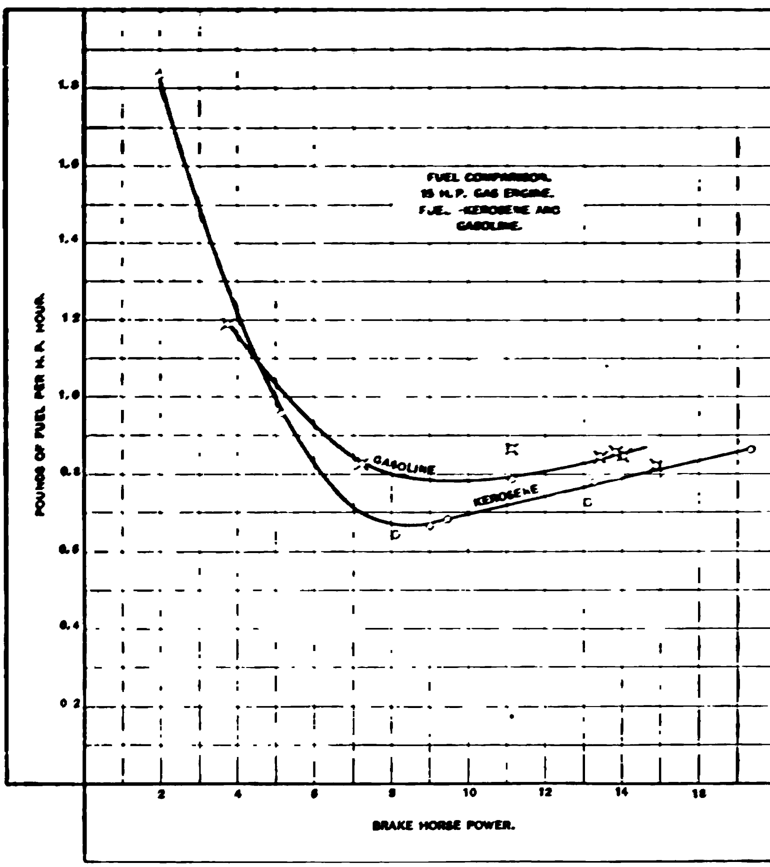


FIG. 203.

mechanical friction of engine, the power developed, the radiation and exhaust.

The heat units converted into useful work and lost in friction were determined from the brake and indicated horse-power measurements. The jacket losses were calculated from the cooling water data. The heat units to be charged to radiation and exhaust could not be found separately. They were obtained by deducting from the total heat supplied the sum of that previously determined for useful work, friction and jacket losses. The heat distribution will, of course, be materially affected by the rate of working the fuel. Its variations may be examined with respect to the rate of working based (a) upon the output of brake horse-

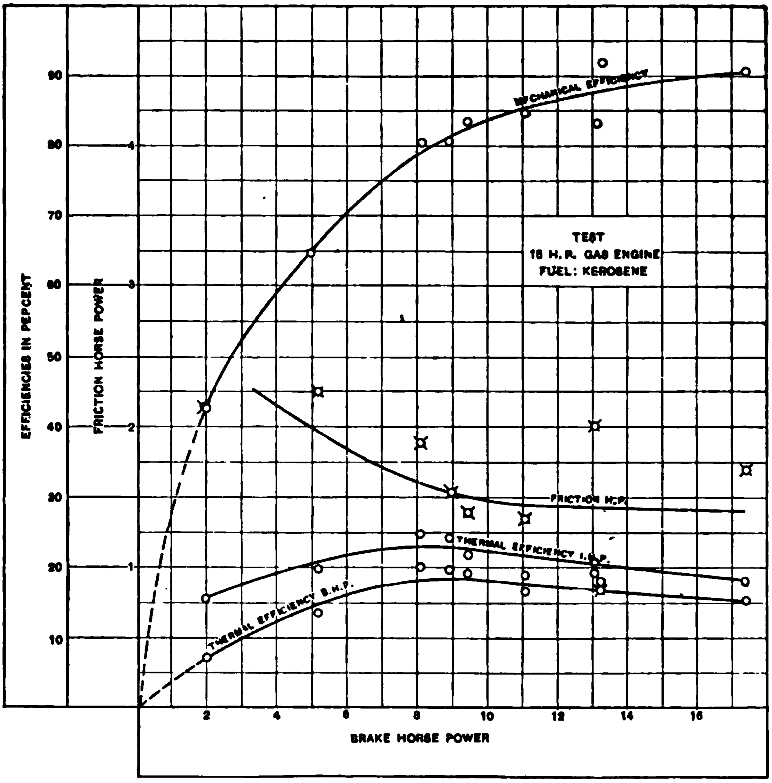


FIG. 204.

power delivered per hour, Figs. 206 and 207; and (b), upon the input of total heat supplied per hour by the fuel, Figs. 208 and 209.

23. The percentage distribution of the total heat supplied was calculated as in Tables V. and VI., and thence plotted in Figs. 206 and 207, respectively, for kerosene and gasoline. On the ordinate for any selected brake horse-power output, the scale distance between any two curves represents the percentage of the total heat expended in that portion of the cycle in the stages noted. The several percentages on the ordinate of any selected brake horse-

power multiplied into the total heat supplied (shown on the same ordinate) will give the heat distribution for the assigned load.

24. The actual distribution of the total heat supplied, reduced to

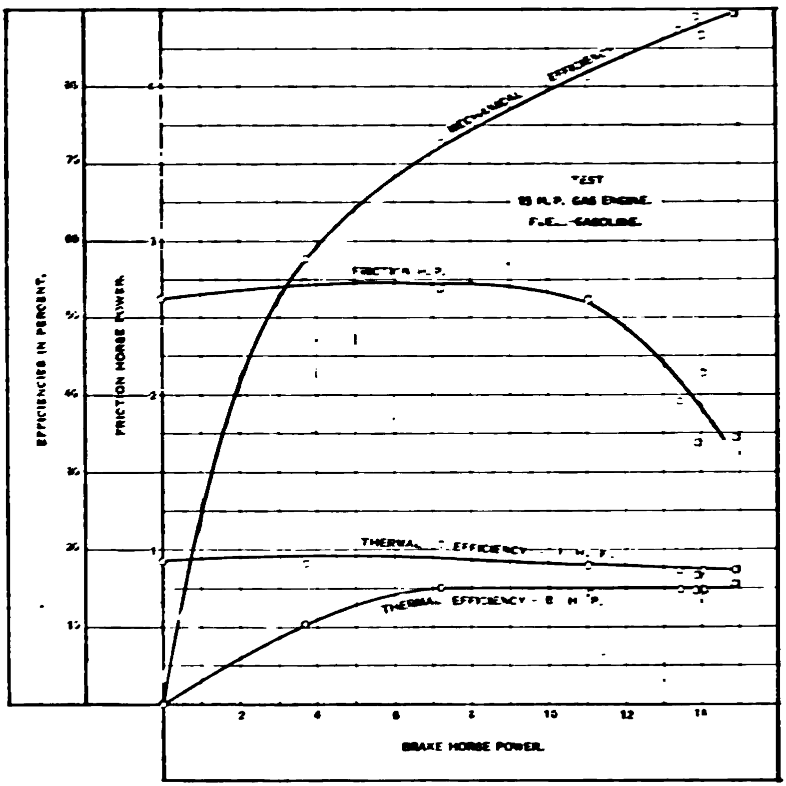


FIG. 205.

one hour basis, Tables V. and VI., has been plotted in Figs. 208 and 209. On the ordinate for any selected total heat input the scale distance between any two curves represents the heat expended in that portion of the cycle in the stages noted.

TABLE I.—DATA AND DIMENSIONS OF GAS ENGINES.

1. Name and number..................................." Otto," No. 5*b*.
2. Manufactured by....... The Otto Gas Engine Co., Philadelphia, Pa.
3. Type..Four cycle.
4. Fuels..............." Water white kerosene" and " Stove gasoline."
5. Heat of combustion { of kerosene............19,282 B. T. U. per lb. / of gasoline............20,296 " " }
6. Horse-power, normal full load ....15 brake ; 18.5 indicated.
7. Floor space.......................7 feet 9 inches × 3 feet 6 inches.
8. Height ....59 inches.
9. Weight..5,000 lbs.
10. Number of cylinders...One.
11. Fly wheel diameter.....................................56 inches.
12. Brake pulley...24 inches.
13. Diameter of piston....................................6½ inches.
14. Piston displacement ....0.3211 cubic foot.
15. Clearance..0.1116 cubic foot.
16. Length of stroke ....15.5 inches.
17. Revolutions per minute (normal).................................260.
18. Governor, fly ball......................" Hit and miss " method.
19. Kind of ignition ....Electric spark.
20. Brake Arm ....63.025 inches.

TABLE II.—MAHLER BOMB CALORIMETER TESTS.—KEROSENE.

Before Combustion.		Combustion.		After Combustion.		Notes.
Minutes.	Temperature.	Minutes.	Temperature.	Minutes.	Temperature.	
0	22.21	5¼	24.74	9	26.00	Kerosene taken, 0.9812 G.
1	22.20	6	25.76	10	25.96	Iron wire taken, 0.0324 G.
2	22.20	7	26.02	11	25.93	Nitric acid found, 0.046 G.
3	22.18	8	26.03	12	25.90	Water used, 2,200 CC.
4	22.18			13	25.86	Water equivalent of Apparatus, 481 CC.
5	22.16			14	25.82	
Average variations per minute, 0.001.		Gross rise in temperature, 3.87 degrees.		Average rate of cooling per minute 0.035.		

Heating value : 10.744 Calories ; 19,339 British thermal units. Sample marked " Water White Oil." Sample No. 4. Test made by Hodge. Date, April 2. 1903. Department of Chemistry, Clarkson School of Technology, Potsdam, N. Y.

TABLE III.—MAHLER BOMB CALORIMETER TEST—GASOLINE.

Before Combustion.		Combustion.		After Combustion.		Notes.
Minutes.	Temperature.	Minutes.	Temperature.	Minutes.	Temperature.	
0	17.81	5¼	18.40	9	18.89	Gasoline taken, 0.2643 G.
1	17.81	6	18.76	10	18.88	Iron wire taken, 0.0135 G.
2	17.81	7	18.88	11	18.88	Nitric acid found, 0.0293 G.
3	17.80	8	18.90	12	18.87	Water used, 2,200 CC.
4	17.80	....	....	13	18.86	Water equivalent of Apparatus, 481 CC.
5	....	....	....	....	....	
Average variations per minute, 0.002.		Gross rise of temperature, 1.10.		Average rate of cooling per minute, 0.008.		

Heating values : 11.277 Calories ; 20,299 B. T. U. Sample marked: " Stove Gasoline." Sample No. 1. Test made by Brand & Halladay. Date, May 3, 1902. Department of Chemistry, Clarkson School of Technology, Potsdam, N. Y.

TABLE IV.—SUMMARY OF DETERMINATION OF HEATING VALUES AND CHEMICAL ANALYSIS OF KEROSENE AND GASOLINE FUELS.

	KEROSENE.	GASOLINE.
Specific gravity, Baumé	49.1°	70°
Flash test	116° F.	...
Fire test	158° F.	...
Commercial name	"Water white oil."	"Stove gasoline."
Cost per gallon on day of test	$0.14	$0.145
HEATING VALUE.		
Samples: No. 1, B. T. U.	19,600	20,299
" " 2, "	18,169	20,700
" " 3, "	20,019	20,403
" " 4, "	19,339	19,784
Average heating value, B. T. U. per pound fuel	19,282	20,296
ULTIMATE ANALYSIS.		
Carbon per cent.	84.13	83.53
Hydrogen " "	13.87	14.14
Sulfur " "	.23	.09
Nitrogen " "	1.77	1.93
		99.69
Oxygen " "	...	.31
Ash " "	...	
	100.00	100.00

Thermal Efficiency and Duty.

25. The thermal efficiency of the conversion of heat into work is shown in Figs. 204 and 205, on the brake horse-power per hour basis as the rate of working; and, in Fig. 210, on the basis of the rate of working, the total heat supplied by the kerosene and gasoline fuels per hour. The former answers the question of how much total heat is required with each fuel to obtain the same net power delivered. The latter answers the question of how much heat will be converted into useful work with a given total amount of heat supplied per hour. In the present case it is quite necessary to consider the latter basis of comparison of the efficiencies of the two fuels. From the average fair curves which have been drawn through the several points, it will be noticed that the maximum efficiency of 19.2 per cent. for the kerosene is reached much earlier in the range of loads than for the gasoline; thence it decreases rapidly to 15.18 per cent. at the maximum full load. With the gasoline, on the other hand, there seems to be a tendency for the efficiency to remain at about the same value of 14.9 per cent. after attaining this maximum.

The thermal duty is here introduced as a further basis for comparing the performance of the engine with kerosene and gasoline fuels. It is defined as the foot pounds of work done by the gas engine per million thermal units supplied by the fuel. It has the same significance as when similarly used to define and compare the performance of pumping engines. As a basis for comparison it is none the less rational than efficiency. It has the added ad-

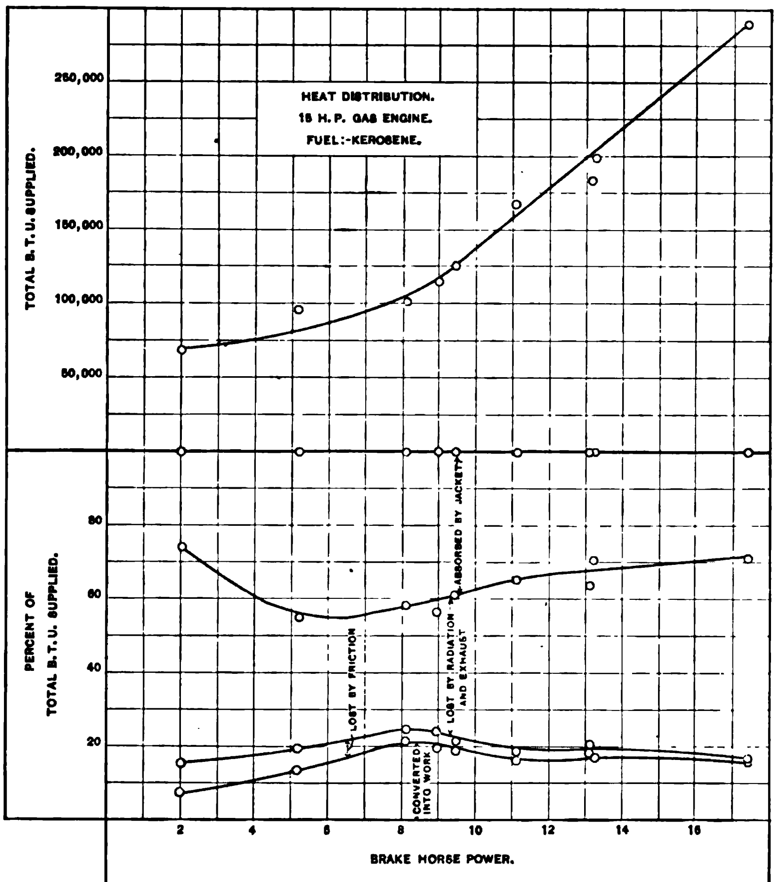


Fig. 206.

vantage of stating a definite output of energy from a given input of thermal units. Where fuels vary so much in heating value as is now coming to be the case with internal combustion engines, it would seem that the duty might be more satisfactory than the efficiency for comparing their performance.

Conclusions.

26. (1) The heating value of the two fuels, as determined by the average of calorimetric tests, was but slightly higher for the gasoline (20,296 British thermal units) than for the kerosene (19,282 British thermal units).

(2) In order to use the kerosene as a power gas in this engine

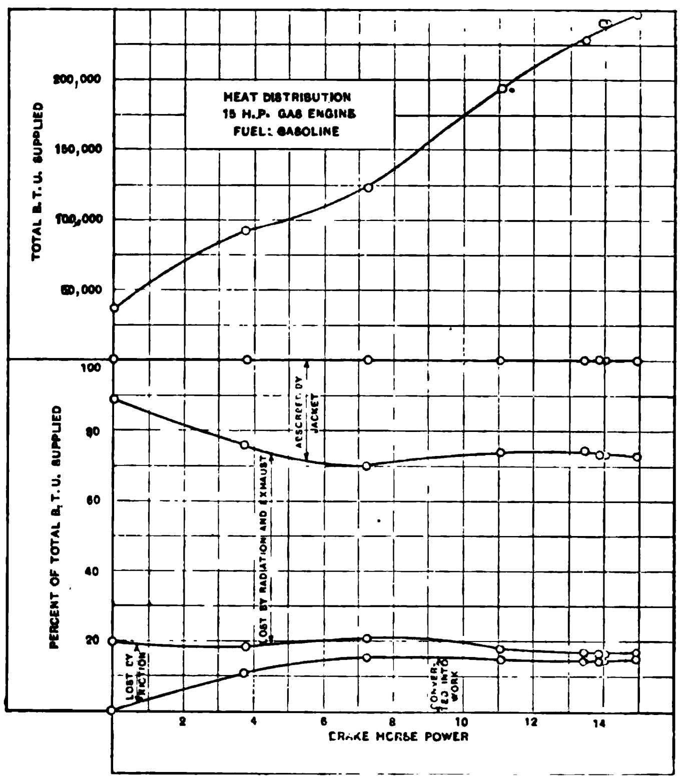


Fig. 207.

it was necessary: (a) to atomize it by compressed air, (b) to vaporize the oil, (c) to superheat the kerosene-air mixture about 250 degrees Fahr. on the average. The kerosene gas was therefore used in a condition somewhat similar to blast furnace and waste power gases for internal combustion engines.

(3) The most satisfactory and economic conditions for the use of the kerosene fuel were found experimentally, by adjusting the

supply of superheated kerosene-air mixture simultaneously with the regular air admission into the engine cylinder, so that the exhaust was smokeless and (by analysis) showed an excess of oxygen.

(4) Capacity tests were made to determine the maximum power delivered under the best operating conditions for economy and speed regulation, giving, for kerosene, a maximum of 17.41 horse-

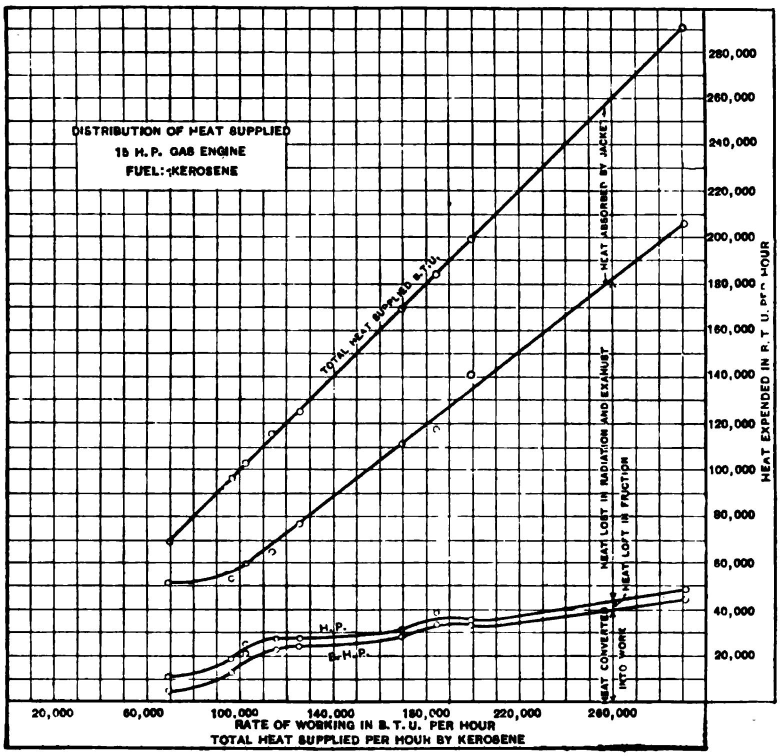


FIG. 208.

power at 309 revolutions per minute; and, for gasoline, a maximum of 14.91 horse-power at 267 revolutions.

(5) The best economic loads for the engine varied with each fuel, being 8.1 brake horse-power for kerosene and 9.5 brake horse-power for the gasoline; that is, for kerosene at about 46 per cent., and for gasoline at about 63.6 per cent. of the maximum full loads for these fuels respectively.

(6) The rate of consumption was the same for each fuel at

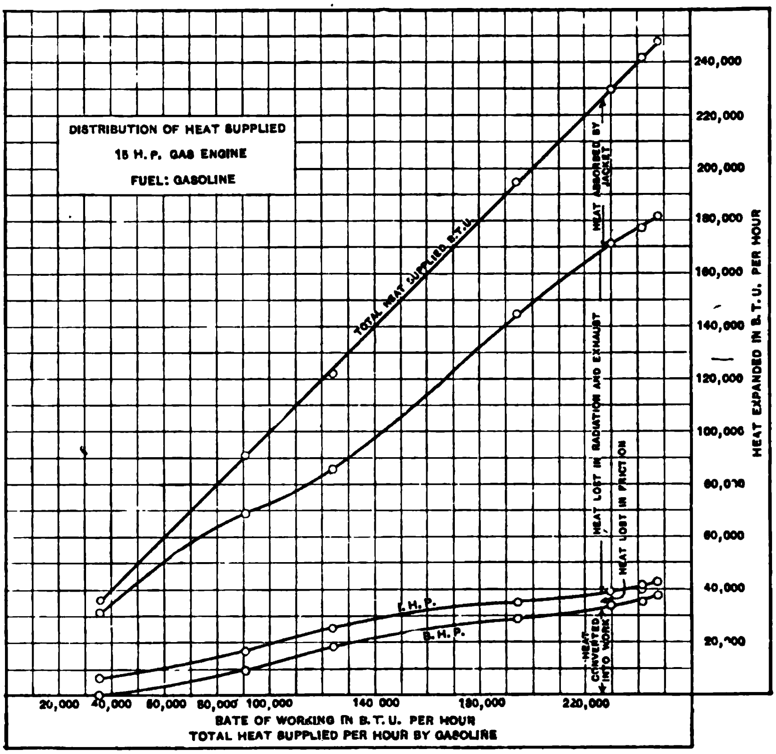


FIG. 209.

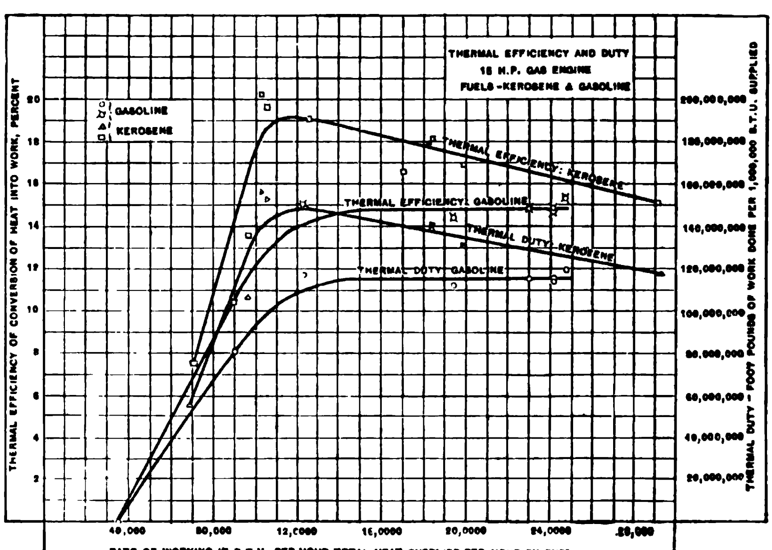


FIG. 210.

about 4.5 brake horse-power delivered; under light loads gasoline was the more economic fuel, while kerosene proved to be the better fuel for high duty heavy load work.

(7) The mechanical friction of the engine did not follow the usual law for prime movers, of constant friction horse-power for all loads at constant speed, but in these experiments it decreased in general as the load increased.

(8) The thermal efficiency was higher for kerosene, having an (average) maximum value of 19.2 per cent. at 9.1 brake horse-power, or, at the rate of working, of 120,000 British thermal units input per hour; and, for gasoline, an (average) maximum of 14.9 per cent. at 9.4 brake horse-power, or, at the rate of working, of 160,000 British thermal units input per hour, which was maintained with but slight variation till the maximum load was reached with gasoline fuel.

(9) The thermal duty, or foot pounds of work done per million thermal units supplied, reached similarly (average) maximum values at above respective loads of 149,000,000 foot pounds for kerosene, and of 116,200,000 foot pounds for the gasoline.

TABLE V.

Average Values and Summary of Results of Tests with Kerosene Fuel.

Number of Test.	Duration of test in minutes.	Barometer, inches.	Average revolutions per minute.	Net weight on brake arm.	Cooling Water.				Temperature of room in Fahr. degrees.	Kerosene consumed per hour in pounds.	Analysis of Exhaust Gases.		
					Initial temperature in Fahr. degrees.	Final temperature in Fahr. degrees.	Difference of temperature in Fahr. degrees.	Weight per hour in pounds.			CO_2.	O.	CO.
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	60	29.11	274	48.00	43.7	152.6	108.9	615	63.02	9.55	11.6	0.8	0.8
2	30	29.10	269	83.00	44.6	155.0	110.4	440	69.00	6.50	11.2	2.2	1.2
3	60	29.11	258	43.00	44.6	116.6	72.0	811	70.05	8.80	11.0	2.0	0.4
4	60	29.10	279	32.00	46.4	116.0	69.6	724	70.84	6.00	8.2	8.2	0.0
5	90	29.11	260	49.00	43.4	99.0	52.6	743	81.86	9.46	4.2	12.9	0.9
6	90	29.11	284	27.00	46.4	122.0	75.6	569	69.56	5.33	2.0	19.0	0.2
7	90	29.12	244	54.00	46.4	126.4	80.0	749	67.28	10.33	7.8	19.2	0.0
8	60	29.11	309	56.25	46.0	129.4	83.4	1,016	55.01	15.05	8.6	7.4	0.8
9	30	29.15	279	7.00	46.4	125.4	79.0	226	75.50	8.60	1.7	15.7	0.8
10	60	29.08	305	17.00	46.4	140.2	93.8	461	65.00	5.00	7.0	14.5	0.4

Number of Test.	Average Gas Temperature.		Average Pressures.			Average Power Developed.			Mechanical efficiency.	Fuel Consumption.	
	Temperature (F.) of super-heated kerosene air mixture.	Temperature (F.) exhaust gases.	Pressure of Compression.	Maximum pressure.	Mean effective pressure.	Indicated horse-power.	Brake horse-power.	Friction horse-power.		Kerosene consumption per I. H. P. per hour in pounds.	Kerosene consumption per B. H. P. per hour in pounds.
	14a	15	16	17	18	19	20	21	22	23	24
1	590	824	51	359	77.50	15.10	13.10	2.00	86.7	.632	.73
2	608	788	38	194	53.34	10.81	9.43	1.38	87.2	.601	.688
3	590	....	51	273	68.84	12.44	11.10	1.34	89.2	.707	.793
4	660	....	38	166	56.06	10.97	8.94	2.03	81.5	.547	.674
5	615	788	52	310	74.32	14.24	12.76	1.48	89.60	.660	.750
6	641	735	30	164	46.57	9.99	8.11	1.88	81.2	.578	.658
7	640	788	52	326	79.00	14.11	13.27	0.84	94.0	.732	.78
8	670	914	60	374	85.64	19.10	17.41	1.69	91.1	.788	.864
9	630	660	17	104	44 05	4.33	1.96	2.37	45.3	.831	1.83
10	630	650	31	138	87.66	7.45	5.19	2.26	69.7	.671	.964

Number of Test.	Distribution of the Total Heat Supplied by the Kerosene.										Thermal duty: Foot pounds of useful work delivered per 1,000,000 B. T. U. supplied by the kerosene fuel.
	Total supplied per hour.	Absorbed by jacket.		Lost by exhaust and radiation.		Lost by friction.		Converted into useful work.		Indicated work.	
		Per Hour.	In per cent. of amount supplied.	Per hour.	In per cent. of amount supplied.	Per hour.	In per cent. of amount supplied.	Per hour.	In per cent. of amount supplied.	In per cent of amount supplied.	
	25	26	27	28	29	30	31	32	33	34	35
1	184,143	66,974	36.30	78,740	42.84	5,090	2.76	33,339	18.10	20.85	140,956,000
2	125,333	48,488	38.68	49,325	39.41	3,520	2.81	24,000	19.10	21.95	148,500,000
3	169,581	58,392	34.35	79,534	46.98	3,420	2.02	28,235	16 65	18.77	129,500,000
4	115,692	50,498	43.70	37,214	32.17	5,187	4.48	22,793	19.65	24.11	153,250,000
5	182,536	39,100	21.42	106,814	58.74	3,764	2.06	32,858	18 00	19.88	139,500,000
6	102,770	43,041	41.80	34,207	33.36	4,782	4.65	20,650	20.19	24.89	156,200,000
7	199,248	59,226	29.75	104,085	52.27	2,137	1.57	33,800	16.90	18.01	131,500,000
8	290,912	84,828	29.10	157,374	54.23	4,350	1.49	44,360	15.18	17.93	118,000,000
9	69,415	17,854	25.67	40,513	58.40	6,040	8.72	5,008	7.21	15.87	56,200 000
10	96,410	43 242	44.85	31,217	35 49	5,749	5.96	13,202	13.70	19.87	105,530,000

TABLE VI.—AVERAGE VALUES AND SUMMARY OF RESULTS OF TESTS WITH GASOLINE FUEL.

Number of Test.	Duration of test in minutes.	Barometer in inches.	Average revolutions per minute.	Net weight on brake arm.	Cooling Water. Initial temperature in Fahr. degrees.	Final temperature in Fahr. degrees.	Difference of temperature in Fahr. degrees.	Weight per hour in pounds.	Temperature of room in Fahr. degrees.	Gasoline consumed per hour in pounds.	Analysis of Exhaust Gases. CO_2	O	CO
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	60	29.33	246.3	57.02	53.6	138.7	85.1	679	86.3	11.31	9.2	6.3	1.8
2	90	29.16	259.5	59.25	54.1	108.9	54.8	1,169	89.2	11.90	6.0	13.0	1.2
3	60	29.21	255.8	54.25	55.4	113.7	58.3	1,099	86.1	11.90	5.6	9.0	1.2
4	60	29.58	267.4	55.75	53.2	104.0	50.8	1,303	79.7	12.20	6.4	8.0	1.4
5	60	29.60	265.3	41.75	57.9	97.4	39.5	1,277	80.3	9.60	6.0	9.2	.4
6	60	29.66	270.8	23.75	64.4	124.2	59.8	609	83.5	6.08	5.0	13.2	0
7	60	29.67	273.3	13.75	64.4	123.5	59.1	376	84.0	4.49	3.4	16.0	0
8	30	29.66	275.2	0.	90.6	12[illegible]	3[illegible].7	208	83.0	1.75	......	..	......

Number of Test.	Average Gas Temperatures. Temperature exhaust gases. Fahr.	Average Pressures. Pressure of compression.	Maximum pressure.	Mean effective pressure.	Average Power Developed. Indicated horse-power.	Brake horse-power.	Friction horse-power.	Mechanical efficiency.	Fuel Consumption. Gasoline consumption per I. H. P. per hour in pounds.	Gasoline consumption per B. H. P. per hour in pounds.
	15	16	17	18	19	20	21	22	23	24
1	788	53	312	93.32	15.39	13.44	1.95	87.50	.735	.845
2	864	54	279	98.44	16.20	14.07	2.13	86.86	.735	.845
3	876	59	308	86.88	15.57	13.88	1.69	89.10	.766	.860
4	866	54	270	88.81	16.64	14.91	1.73	89.70	.733	.820
5	820	58	328	96.71	13.69	11.07	2.62	81.00	.700	.868
6	644	54	298	102.34	9.95	7.25	2.70	72.80	.606	.831
7	510	57	256	98.85	6.49	3.75	2.74	57.80	.692	1.190
8	....	55	164	82.16	2.63	0.	2.63	0.	.667	.0

Number of Test.	Distribution of the Total Heat Supplied by the Gasoline. Total heat supplied per hour.	Absorbed by jacket. Per hour.	In per cent. of amount supplied.	Lost in exhaust and radiation. Per hour.	In per cent. of amount supplied.	Lost in friction. Per hour.	In per cent. of amount supplied.	Converted into useful work. Per hour.	In per cent. of amount supplied.	Indic'd work. In per cent. of amount supplied.	Thermal Duty: Foot pounds of useful work delivered per 1,000,000 B. T. U. supplied by the gasoline fuel.
	25	26	27	28	29	30	31	32	33	34	35
1	229,527	57,783	25.17	132,607	57.78	4,937	2.15	34,200	14.90	17.05	115,900,000
2	241,501	64,200	26.58	136,047	56.34	5,446	2.25	35,808	14.83	17.08	115,400,000
3	241,501	64,092	26.54	137,789	57.06	4,301	1.78	35,318	14.62	16.40	113,800,000
4	247,589	66,192	26.73	138,995	56.14	4,402	1.78	38,000	15.35	17.13	119,400,000
5	194,824	50,441	25.89	109,512	56.23	6,668	3.42	28,173	14.46	17.88	112,500,000
6	122,874	36,418	29.76	60,625	49.54	6,880	5.62	18,451	15.08	20.70	117,300,000
7	91,120	22,221	24.39	52,357	57.46	6,999	7.68	9,543	10.47	18.15	81,500,000
8	35,511	4,035	11.36	24,786	69.79	6,693	18.85	0	0	18.85	0

TABLE VII.—EXHAUST GAS TEMPERATURE AND ANALYSIS.

	Kerosene.				Gasoline.			Kerosene.			Gasoline.		
			Corresponding.			Corresponding.		Exhaust gases.			Exhaust gases.		
	Degree super-heat of vapor. F.°	Temperature exhaust gases F.°	B. H. P. delivered.	Per cent. full load.	Temperature exhaust gases F.°	B. H. P. delivered.	Per cent. full load.	CO_2	O	CO	CO_2	O	CO
Maximum..	290	914	17.4[illegible]	100.0	860	14.91	100.0	11.6	15.7	1.2	9.2	16	1.8
Minimum..	210	476.4	1.9[illegible]	6.9	511.	3.75	25.0	1.7	0.8	0.	3.4	8.0	0.
Average....	248	768	......	.....	770	......	......	5.6	12.6	0.5	5.7	9.9	1.06

No. 991.*

TESTS OF A TWELVE-HORSE-POWER GAS ENGINE TO DETERMINE THE EFFECTS OF CHANGES IN SPEED, LOAD, POINT OF IGNITION, RATIO OF GAS TO AIR, AND JACKET TEMPERATURE.†

BY C. H. ROBERTSON, LAFAYETTE, IND.
(Junior Member of the Society.)

Introductory.

1. For some years the Institution of Civil Engineers of England has been maintaining a committee on gas engine research. Much painstaking and carefully conducted work has been carried on in Germany and France, and within the last few years not a little attention has been given to the subject in the United States. With the hope of being able to contribute something to the better understanding of the relations of some of the factors of the problem for the Otto-cycle gas engine, and along the same general lines as some of the above-mentioned facts, an investigation was begun in the laboratories of Purdue University in 1896, and has been continued since that time. The nature of the problem and the relative importance of its various factors will depend in a large measure on the standpoint of the inquiry, whether that of construction, operation, or finance. The relations of the vari-

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions.*

† For further discussion on the same topic consult *Transactions* as follows:

No. 843, vol. xxi., p. 396: "An Efficiency Test of a One Hundred and Twenty-five Horse-power Gas Engine." C. H. Robertson.

No. 875, vol. xxii., p. 152: "Efficiency of a Gas Engine as Modified by Point of Ignition." C. V. Kerr.

No. 895, vol. xxii., p. 612: "Efficiency Tests of a One Hundred and Twenty-five Horse-power Gas Engine." C. H. Robertson.

No. 949, vol. xxiii., p. 686: "Temperature of Exhaust Gases." R. H. Fernald.

No. 950, vol. xxiii., p. 705: "Working Details of a Gas Engine Test." R. H. Fernald.

ous factors are complicated, too, by the fact that a change in one may produce a change in several others, the character and extent of which will depend upon the circumstances imposed.

2. The difficulties of an investigation of the sort here reported may be better appreciated, perhaps, when it is known that no very satisfactory advance in the problem as a whole was made until the fourth year of investigation. In the attempt during the fifth year to verify the results of the fourth a number of contradictions were met which necessitated a sixth year's work in order to determine which of the two previous years' records should be accepted.*

Facilities for Making Tests.

3. Thus far 346 tests have been run, only a part of which are reported in this paper All have been made upon a $6\frac{3}{4} \times 15\frac{7}{16}$ Otto gas engine (Fig. 211) rated at 12 horse-power, and having a normal speed of 270 revolutions per minute. A break spark electric igniter is used, which receives its current through a sparking coil from a 5-cells chemical battery. The speed is controlled by a weighted fly-ball governor acting on the hit and miss principle. By using a series of different governor weights the speed can be varied from 150 to 300 revolutions per minute.

The indicated horse-power of the engine is determined by means

* The tests during the first three years of this series were carried out under the general direction of Prof. R. A. Smart, while those of the last three years has been made under the supervision of the writer. Great credit is due to the authors of the following theses, who as students in Purdue University, exhibited much energy, patience and skill in carrying forward the details of observing, recording and reducing the data.

"The Performance of a Twelve-Horse-power Otto Gas Engine Using Natural Gas." A thesis by E. G. Crozier, B.S., '96.

"The Performance of a Twelve-Horse-power Otto Gas Engine Using Natural Gas." A thesis by W. D. Findley, B.S., '98.

"The Performance of a Twelve-Horse-power Otto Gas Engine Using Natural Gas." A thesis by L. L. Johnson, B.S., '99.

"A Series of Tests on a Twelve-Horse-power Otto Gas Engine under Various Conditions." A thesis by R. S. Coburn, B.S., and A. O. Vandervoort, B.S., '00.

"Tests of a Twelve-Horse-power Otto Gas Engine to Determine the Effect of Changes in Speed, Load, Gas Mixture, Jacket Temperature, and Ignition." A thesis by Bruce Rollman, B.S., '01, and O. Z. House, B.S., '01.

"A Series of Tests on a Twelve-Horse-power Otto Gas Engine to Determine the Effect of Changes in Various Factors." Two theses by E. M. May, B.S., '02, and R. I. Rheinstrom, B.S., '02.

of a Crosby indicator driven from a pendulum-reducing motion. The power delivered to the fly wheel is absorbed and measured by a Prony friction brake connected to a pendulum weight, which is so calibrated as to read the pull in pounds at the end of the brake arm. The engine is provided with separate counters for determining the number of revolutions and the number of explosions; the former by connection with the indicator rigging, and

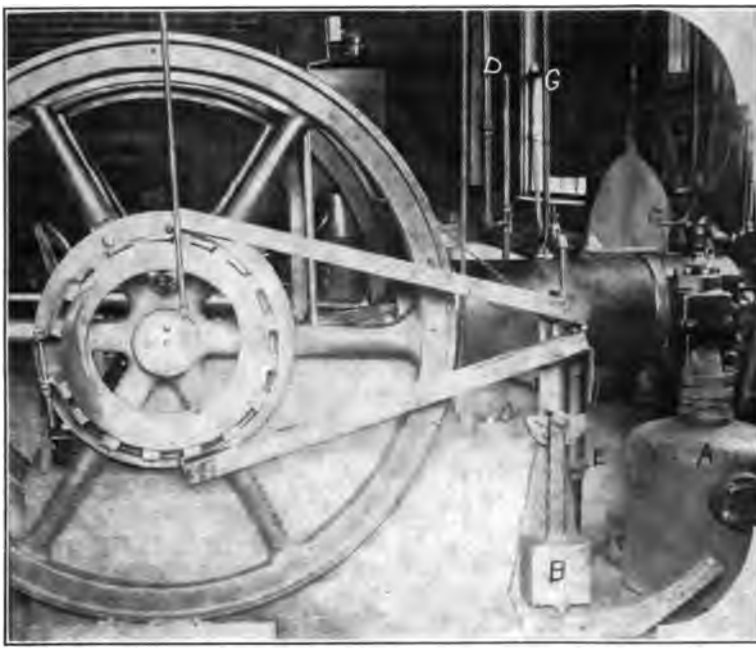


FIG. 211.—THE ENGINE AND ITS EQUIPMENT.

the latter by means of a mechanism receiving its impulses from the burnt gases as they escape from the exhaust pipe.

4. Natural gas is used in all tests, its heating value being about 970 British thermal units per cubic foot when reduced to standard conditon of 14.7 pounds pressure and 62 degrees Fahr. temperature. It is measured by means of a Westinghouse wet gas meter, suitable arrangements being provided for observing the pressure and temperature of the gas as delivered by the meter to the mixing valve of the engine. The mixing valve is of the plug-cock type, having the pointer on its handle swinging over an arc graduated in notches, so as to read from zero to ten in going

from the closed to full open position. These markings have no particular significance in regard to the proportion of gas to air, and merely indicate the degree of opening of the valve.

5. Provision was made for determining the amount of air consumed by the engine during certain of the tests by, first, providing a source of compressed air which was permitted to flow through a small orifice, previously calibrated, into a large rubber bag, whence it was conducted by a short 1½-inch pipe line to the base of the engine, which had previously been made air-tight, and was thus caused to act as a reservoir from which the engine drew its air supply. In order to secure the same condition during those tests when the air was being measured, as obtained when the engine was taking its air by suction through the base, a small water gage meter was connected to the base, and observations made of the pressure therein when the engine was running normally. When the tests were run in which the air was measured, this gage meter served as a guide for regulating the flow of air to the base in such a manner as to secure the same vacuum as was observed when the engine was taking its air by suction. In order to protect the rubber air-regulating bag from excessive pressures, a suitable water-sealed safety valve was connected to the 1½-inch pipe line. A gage and thermometer placed just above the orifice for measuring the air served to show the pressure and temperature, and these, with the data of a previous calibration of the orifice, made it possible to determine quite exactly the amount of air used.

6. Thermometers inserted in the pipes just before and after the openings in the jacket served to determine its initial and final temperatures, which with the weight of water, as determined by weighing barrels and scales, made it possible to calculate the amount of heat absorbed by the jacket of the engine.

Tests

7. The data presented in this paper are a part of those secured during the fifth and sixth years of the investigation. Throughout the entire set of each year two persons made all observations, each test lasting fifteen minutes, with time between to allow the [illegible] to become [illegible]. Readings were taken at five minute intervals. A summary of the factors investigated is as follows:

I. Proportion of gas to air.
II. Jacket temperature.
III. Time of ignition.
IV. Revolutions per minute.
V. Horse-power.

A graphic outline of these tests arranged so as to show each series with its variables and constants is as follows: Each "X" representing a test and the coördinate factors opposite it showing the condition of the variable factors for that test, while the constants of the series are stated at the right.

SERIES 1.—ON MIXTURE OF GAS AND AIR.

Notch of Mixing Valve.						
9	X	X	X	X		
8	X	X	X	X		
7	X	X	X	X		
6	X	X	X	X		
5	X	X	X	X	X	
4	X	X	X	X	X	X
3	X	X	X	X	X	X
2	X	X	X	X	X	X
Brake horse-power.	0	2	4	6	8	10

Constants.
Revolutions per minute = 270.
Point of ignition normal.
Jacket temperature = 140° F.

SERIES 2.—ON JACKET TEMPERATURE.

Jacket Discharge Temperature.						
200	X	X	X	X	X	X
160	X	X	X	X	X	X
120	X	X	X	X	X	X
90	X	X	X	X	X	X
Brake horse-power.	0	2	4	6	8	10

Constants.
Revolutions per min. = 270.
Ignition = normal.
Notch = 3.5.

8. The cooling water enters the jacket at the bottom and escapes at the top. Its temperature is measured just before entering and just after leaving the jacket. The average temperature of the jacket must have been somewhere between this initial and final temperature, and probably nearer the latter than the former. In the absence of more definite information on this

point, the term "jacket temperature" is used in the discussion in the sense of being that of the escaping water.

SERIES 3.—ON TIME OF IGNITION.

Ignition.	0	2	4	6	8	10
Early..	X	X	X	X	X	X
Normal	X	X	X	X	X	X
Late...	X	X	X	X	X	X

Brake horse-power.

Constants.
Revolutions = 270.
Notch = 3.5.
Jacket temperature 160° F.

9. The significance of the terms early, normal, and late ignition as used in this paper is suggested by Fig. 3. In early ignition the explosion takes place considerably before the end of the compression stroke, and gives a very sharp peak on the indicator diagram, the explosion line making an angle of about 10 degrees with the vertical. With normal ignition the explosion takes place slightly before the end of the compression stroke, so as to give as nearly as possible a vertical explosion line. In late ignition the explosion occurs either at or just after the end of the compression stroke, and gives an explosion line that slopes forward from the vertical, making an angle of about 18 degrees.

SERIES 4.—ON REVOLUTIONS PER MINUTE.

Revolutions per Minute.	0	2	4	6	8	10	12
300	X	X	X	X	X	X	X
270	X	X	X	X	X	X	
240	X	X	X	X	X	X	
210	X	X	X	X	X		
180	X	X	X	X	X		
150	X	X	X	X			

Brake horse-power.

Constants.
Notch = 3.5.
Ignition = normal.
Jacket temp. = 160° F.

Observed and Calculated Results.

10. In each test the following observations were taken: Revolution per minute, explosion per minute, brake load, indicator cards, weight of jacket water, initial and final temperature of jacket

water, temperature, pressure and amount of gas consumed, and the barometric pressure.

With these data it became possible to calculate the following factors:

Mean effective pressure.

Indicated horse-power.

Brake horse-power.

Frictional horse-power.

Mechanical efficiency.

Gas per indicated and per brake horse-power per hour.

Thermal efficiency based on indicated and on brake horse-power.

Amount and percentage of heat absorbed by the jacket and by exhaust and radiation.

Constants and Formulæ.

11. The constants employed in connection with the averaged values of observed results (not given) are as follows:

The piston is $6\frac{3}{4}$ inches in diameter, and has a stroke of $15\frac{7}{16}$ inches.

The clearance is 35.2 per cent. of piston displacement, or 26 per cent. of cylinder volume.

Normal speed, 270 revolutions per minute.

Heat value of the gas is 970 British thermal units per cubic foot standard gas.

Standard gas is gas at a pressure 14.7 pounds absolute per square inch, and at a temperature 62 degrees Fahr.

Brake horse-power is .00633 multiplied by revolutions per minute multiplied by brake load.

Indicated horse-power is .001395 multiplied by explosions per minute multiplied by mean effective pressure.

Thermal efficiency is the heat equivalent of the horse-power divided by the total heat to produce that horse-power, and is based upon the brake horse-power and indicated horse-power performances respectively.

The mechanical efficiency is the brake horse-power divided by the indicated horse-power.

The heat lost due to exhaust and radiation is the total heat less (the sum of the heat equivalent of the brake horse-power and the heat absorbed by jacket water).

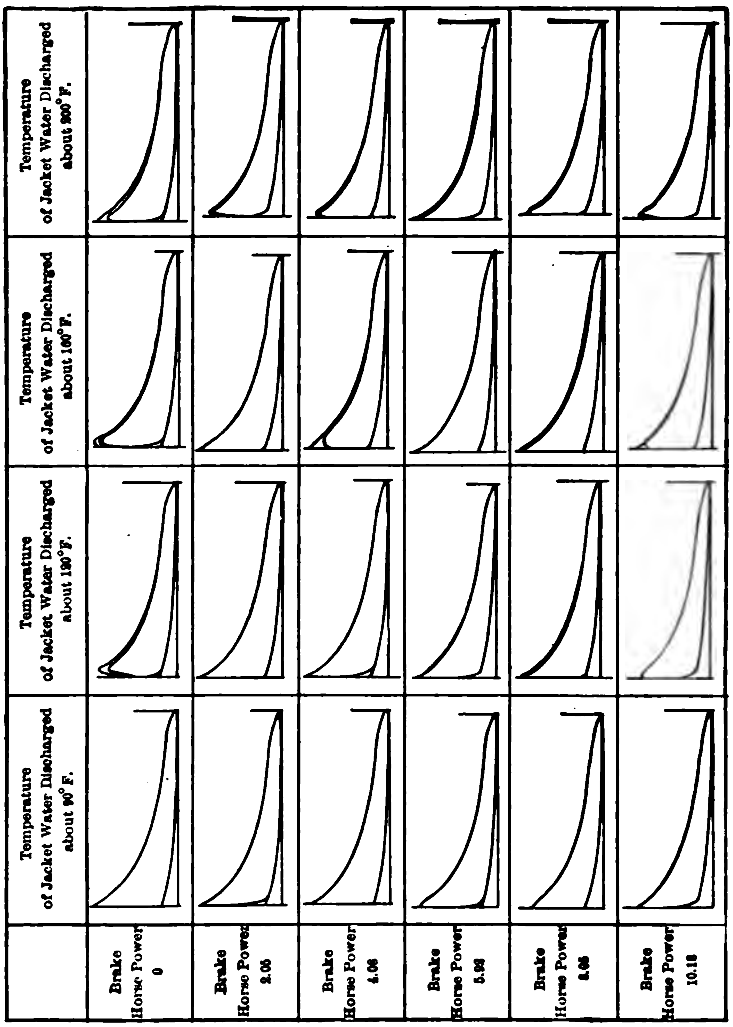


FIG. 212.—SAMPLE INDICATOR CARDS REPRESENTING SERIES 2,

Showing changes in the form of the card resulting from changes in the temperature of the jacket.

Results.

12. The results of the tests are in part presented in the form of indicator cards, Figs. 212 to 215 inclusive, and in part in the form of plotted diagrams, Figs. 216 to 221, inclusive.

Concerning Air and Gas Mixture Series.

13. It is very much to be regretted that the series of tests concerning the effect of change in the proportion of gas to air have

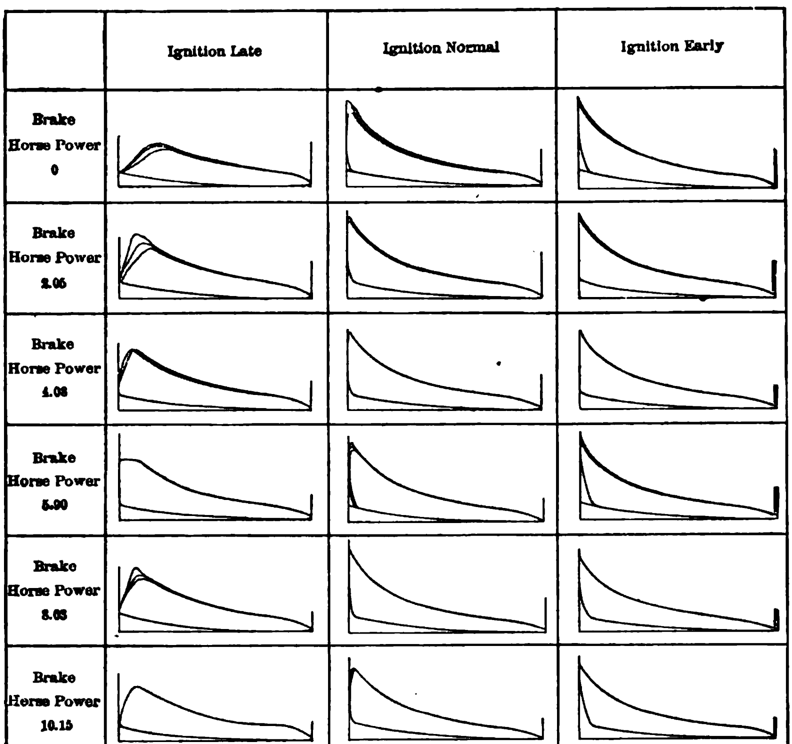


FIG 213.—INDICATOR CARDS REPRESENTING SERIES 3, Showing changes in the form of the card resulting from changes in the time of ignition.

not proven as satisfactory as was desired. On this account the data on that subject will be reserved for future consideration after some points on a part of the curves have been reinvestigated. This is so important a factor, however, and has such a definite bearing upon the effect of other factors, that it is necessary to present some conclusions concerning it to serve as a basis from which to explain the effect of changes in some other of the main factors of the investigation. These conclusions are based upon the curves shown in Fig. 222, which curves were plotted

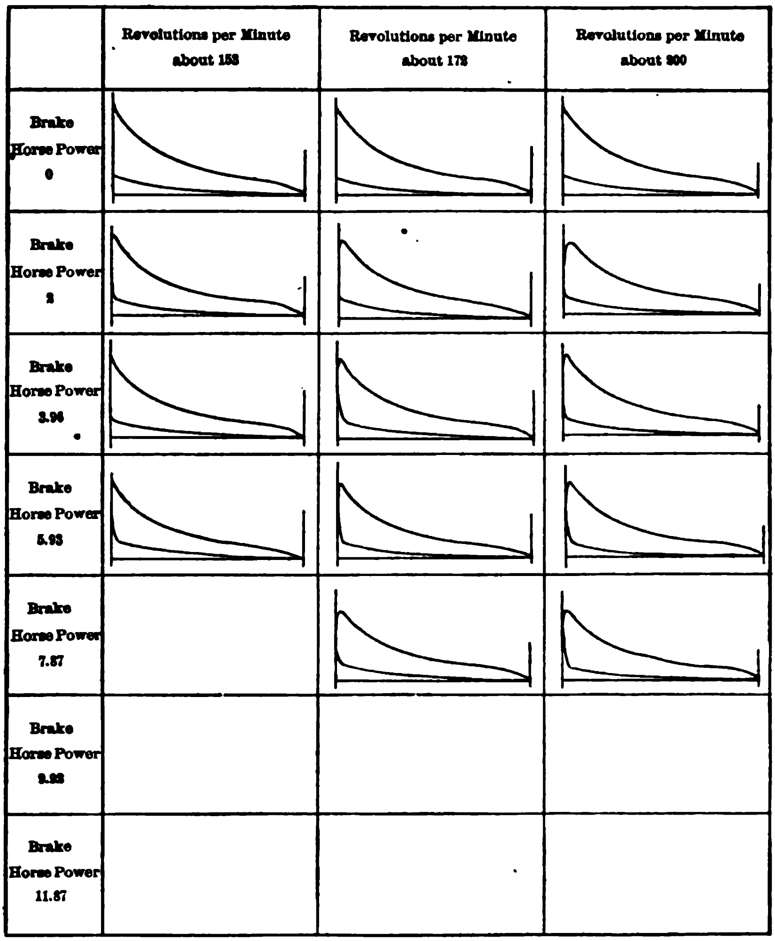


FIG. 214.—INDICATOR CARDS REPRESENTING SERIES 4,
Showing changes in the form of the card resulting from changes in speed.

from the data of the sixth year's work, and which show the relation between the notch of the mixing value and the ratio of gas to air for the horse-powers of 0, 2, and 4.

The curves show:

First. At a given notch, speed, jacket temperature, and point of ignition, that the ratio of gas to air decreases as the horse-power is increased.

Second. The effect of a given change in the position of mixing

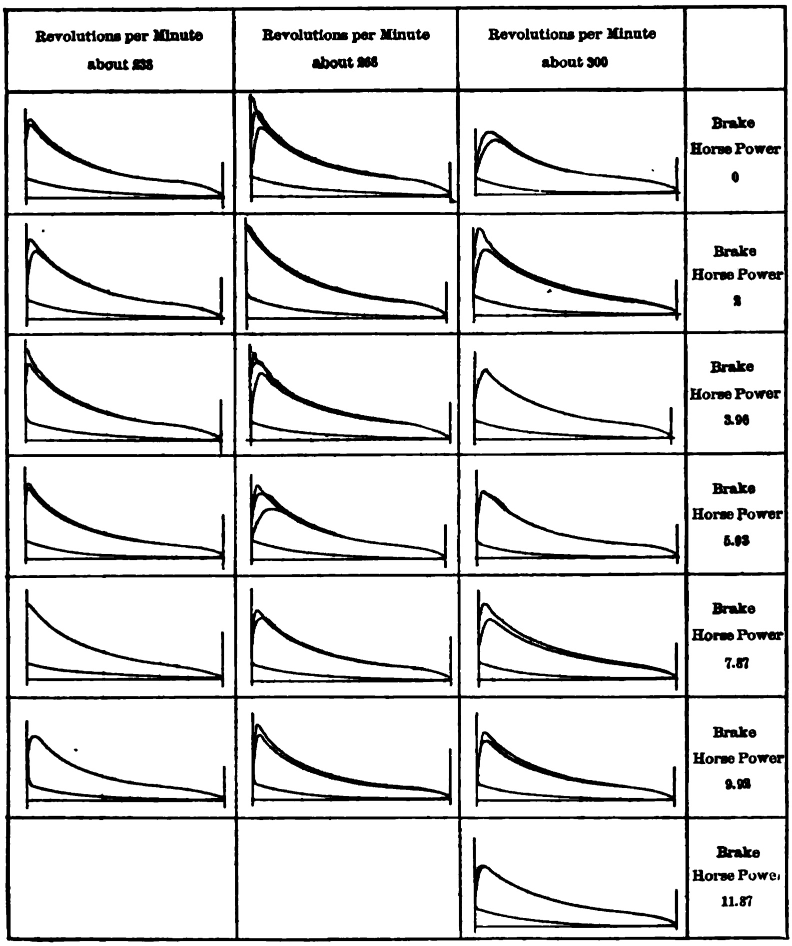


FIG. 215.—INDICATOR CARDS REPRESENTING SERIES 4 (COMBINED), Showing changes in the form of the card resulting from changes in speed.

valve upon the ratio of gas to air is very much more marked at the lower than at the higher notches.

14. From the other data of this series it has been found that the notch at which the mixing valve is set is an important factor in the gas economy of the engine, that a change of its position

has a marked influence upon mean effective pressure, and that the extent and character of this influence is different for different horse-powers, that on an average the engine runs with the greatest

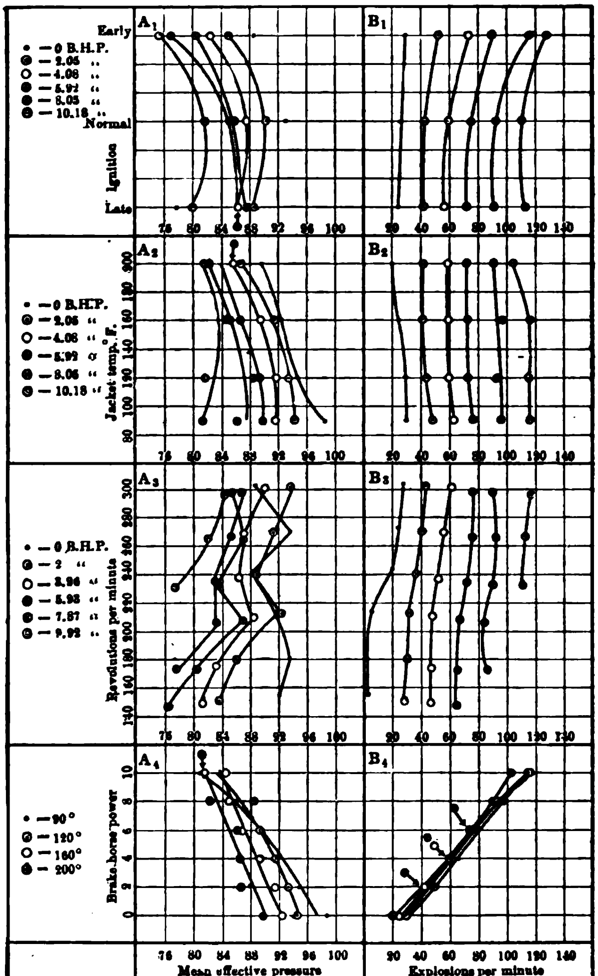


FIG 216.—MEAN EFFECTIVE PRESSURE AND EXPLOSIONS PER MINUTE
As affected by changes in the time of ignition, temperature of jacket, speed, and horse-power.

economy if the mixing valve is at notch $3\frac{1}{2}$, and that an increase of horse-power necessitates a slight decrease in the notch position to secure the highest economy. The change of mean effective pressure produced by a change in the setting of the gas valve is

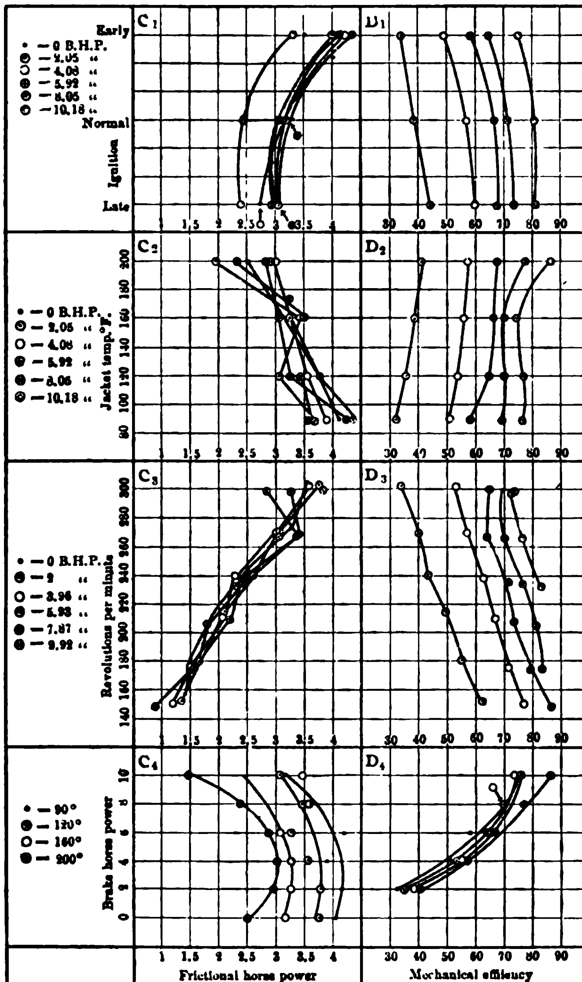


Fig. 217.—Frictional Horse-power and Mechanical Efficiency

As affected by changes in time of ignition, temperature of jackets, speed, and horse-power.

accompanied by a change in mechanical efficiency. In all tests in which other factors than ratio of gas to air was being considered, the mixing valve was kept at this best average notch of 3½.

A Graphical Presentation of Results and Conclusions Therefrom.

15. In considering Figs. 216 to 221, it should be remembered that at best it is possible to show the relation between a main

factor and a subordinate factor only by adopting some expedient which will show the value of one of the other main factors, upon

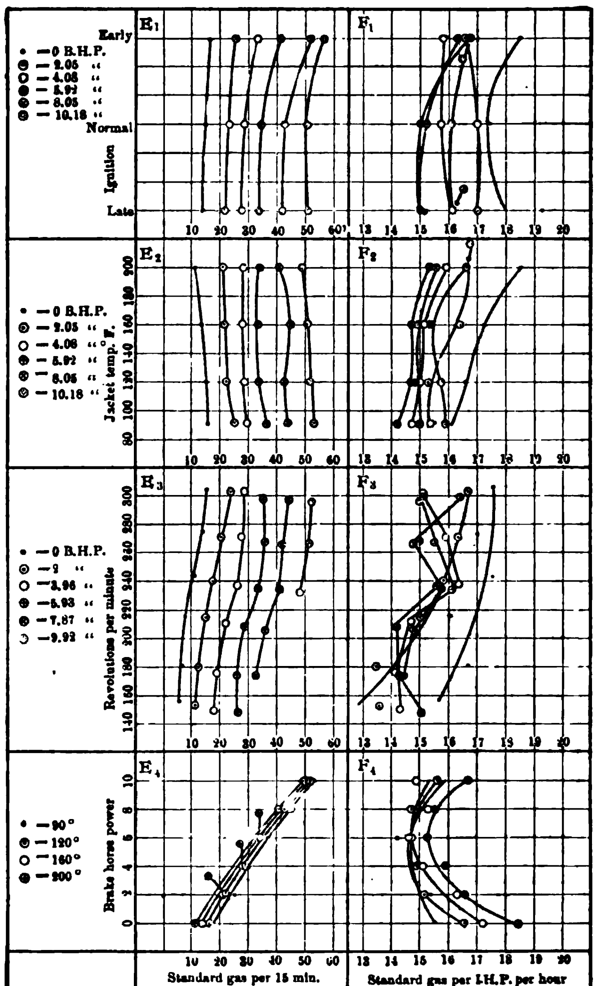


FIG. 218.—GAS CONSUMPTION FOR THE TEST AND PER INDICATED HORSE-POWER PER HOUR

As affected by changes in the time of ignition, temperature of jacket, speed, and horse-power.

which in no small measure the relations of the first two depend—that is to say, if it is desired to show the effect of changes of the point of ignition upon the mean effective pressure, it is important that the horse-power of the engine be kept constant. Preferably, this should be the indicated horse-power, but as it is practically

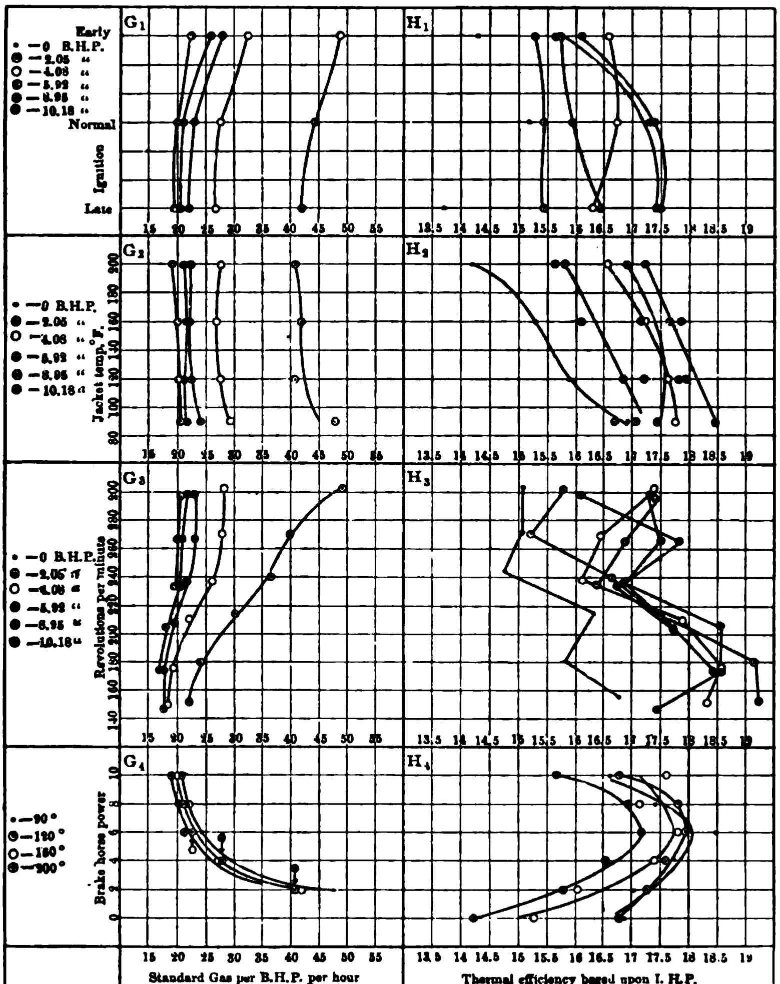


Fig. 219.—Standard Gas per Brake Horse-power and Thermal Efficiency As affected by changes in time of ignition, temperature of jacket, speed, and horse-power.

impossible to secure and observe such a condition, the tests were run on the basis of a series of constant brake horse-powers.

In Figs. 216 to 221 each curve in the three upper portions of the diagrams represents a constant brake horse-power, the value of the power being indicated by the note of reference at the left. In the lower portions of the diagrams each curve represents a con-

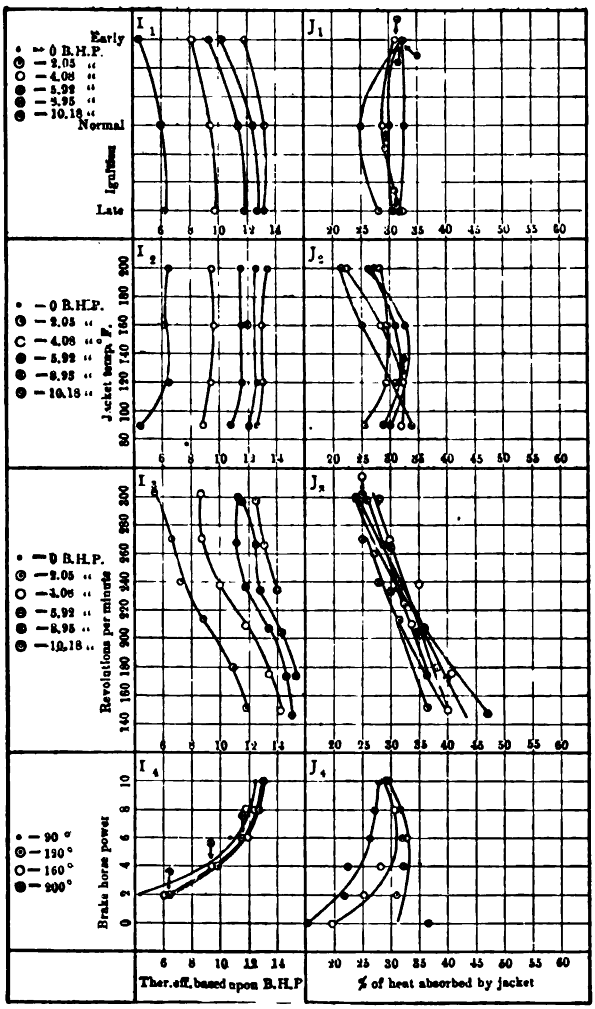


FIG. 220.—THEORETICAL EFFICIENCY AND PER CENT. OF HEAT ABSORBED BY JACKET.

As affected by changes in time of ignition, temperature of speed and horse-power.

stant temperature of jacket. While it is clear that comparisons between the several diagrams will permit the construction of curves showing relations other than those which are presented, it is nevertheless believed that the diagrams as given constitute a complete record of the experimental results, and for this reason the usual array of numerical results is entirely omitted.

Conclusions Concerning the Effect of Changes in the Point of Ignition.

16. By referring to the curves it may be seen that the mean

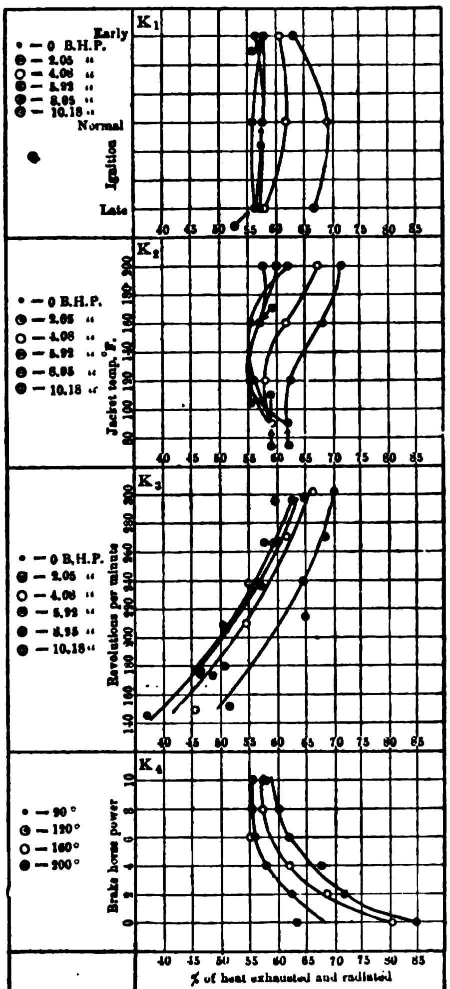


FIG. 221.—HEAT EXHAUSTED AND RADIATED
As affected by changes in time of ignition, temperature of jacket, speed, and horse-power.

effective pressure for early ignition is considerably less than for normal, which in turn is better than for late. The shape of the curves indicates two things: first, that the highest mean effective pressure is secured between normal and late, and probably considerably closer to the former than the latter; and, second, that an increase of horse-power calls for a later point of ignition if

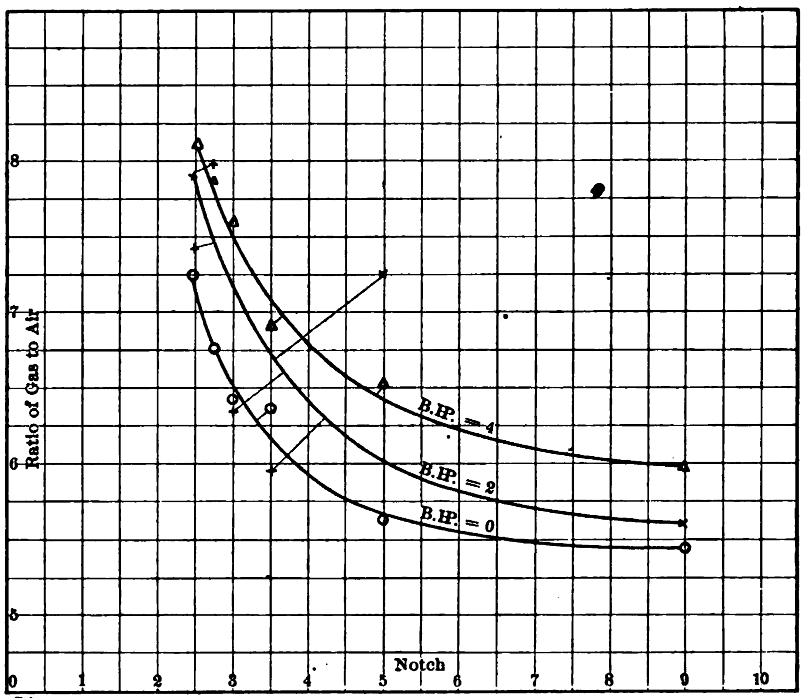


FIG. 222.—POSITION OF MIXING VALVE AND RATIO OF GAS TO AIR.

the highest mean effective pressure is to be secured. It may also be observed from the curves C_1, Fig. 217, designated "frictional horse-power," that the early ignition causes a considerable increase in frictional horse-power. Since these curves are all drawn at constant horse-powers, this means a decrease in mechanical efficiency, as shown in the curves D_1, Fig. 217.

17. This results in the necessity of an increase of the number of explosions per minute, curves B_1, Fig. 216, to carry the horse-powers as designated, and consequently an increase in the gas consumed per fifteen minutes per indicated and per brake horse-power per hour, as shown by E_1, F_1, and G_1, respectively, Figs.

218 and 219. These gas consumption records mean, of course, a decrease in thermal efficency based upon both the indicated and the brake horse-powers, as shown by H_1 and I_1, Figs. 219 and 220. The decrease in efficiency is considerably based upon both the indicated and the brake horse-powers, as greater at the lower and higher horse-powers of zero and 10 than it is for the medium horse-powers 6 and 8.

18. From the curves J and K shown, we note two conclusions: first, that on the average the late ignition is better than the normal, and considerably better than early; second, that the best point of ignition is probably between normal and late, and closer to the latter than to the former.

The net change in the amount of heat absorbed by the jacket and in exhaust and radiation in passing from normal to late ignition, the sum of which on an average amounts to an increase of 1.66 per cent., is probably due in part to the increase in the frictional horse-power, which on the average increases 1.61 per cent. It is to be regretted that the series was not continued with the still later ignition for each of the horse-powers. The object of the investigation, however, was to find that point which would give the best performance.

Conclusions Concerning Changes in Jacket Temperatures.

19. By referring to the sets of curves opposite the jacket temperature scale, it is seen that for all horse-powers excepting 10 an increase in jacket temperature produces a decrease in the mean effective pressure, and that this effect is more marked at low than at high horse-powers, A_3, Fig. 216. Notwithstanding this decrease in mean effective pressure, the engine requires fewer explosions per minute at the high jacket temperature to carry the horse powers, as is shown by the next curves, B_2, Fig. 216. This is explained mainly by the next set of curves, C_2, Fig. 217, which shows that the increased jacket temperature produces a very marked decrease in frictional horse-powers, which on an average is represented by the following formula:

$$\text{F.H.P.} = \frac{426 - t}{86.6}$$

in which F.H.P. = Frictional horse-power,
t = Jacket temperature ° F.

20. The curves B_2 and C_2 indicate, of course, that the mechanical efficiency is increased, and that the gas per fifteen minutes to carry these horse-powers is decreased, as is illustrated by curves D_2 and E_2. The decrease of frictional horse-power due to increase of temperature of jacket from 90 to 200 degrees is (1.27), and the corresponding increase in mechanical efficiency is 8.9 per cent.

By dividing the gas per fifteen minutes by the explosions in that time, it is found that the increase in jacket temperature is accompanied by an increase in the amount of gas per explosion, thus showing that the decreased mean effective pressure is not due to a decrease in the amount of gas. This means, of course, that the economy based upon the cylinder performance is impaired by the increase in jacket temperature. It is of interest to observe that the decrease in explosion per minute must result in an increased scavenging effect due to blank charges of air, which it would seem should tend to produce an increase in the mean effective pressure. Possibly the change of jacket temperature causes a change in the proportion of gas to air sufficient to account for the decrease in mean effective pressure. The increase in gas per indicated horse-power per hour is shown by curves F_2, Fig. 218, while the gas per brake horse-power per hour, curves G_2, Fig. 217, is seen to decrease. This is a good illustration, of which there are a number in the investigation of a conflict of interests between mechanical and thermal considerations. The increased jacket temperature produces a decreased mean effective pressure and an increase in the gas per indicated horse-power per hour, but notwithstanding these disadvantages, the increased temperature is so beneficial from the mechanical standpoint in decreased friction that the gas per brake horse-power per hour and the thermal efficiency based upon the same show a considerable improvement.

21. Passing to the next set of curves, J_2, Fig. 219, showing the per cent. of heat absorbed by the jacket, it is seen in general, and as might be expected, that an increase in jacket temperature produces a decrease in the amount of heat absorbed by the jacket. The curves K_2, Fig. 220, show on the average that the increase in jacket temperature causes an increase in the percentage of heat exhausted and radiated. These two latter factors are considerably affected by the decrease in friction, as shown by curves C_2.

Under certain circumstances it may be that the saving of jacket water by using a high temperature of discharge may be an important factor. This saving of water may be no small amount. Take, for illustration, the case of the engine carrying 6 horse-power, with a jacket temperature of 200 degrees 66.5 pounds of water were used, while at 90 degrees 337 pounds were required. The higher temperature thus requiring but .2 as much water as the lower.

Conclusions Concerning the Effect of Changes in Speed.

22. The sets of curves next below those just considered, and designated by the subscript 3, show the effect of changes in revolutions per minute. The first result we notice of an increase in speed from 150 to 300 revolutions per minute is a marked increase in the mean effective pressure. The curves concerning this factor are somewhat irregular, but the fact that in all sets they are in the main parallel, indicates that the irregularity is in some way dependent upon the changes in speed. This increase in mean effective pressure is most marked at the higher horse-powers, where it amounts to an increase of 7 pounds when changing from 232 to 298 revolutions per minute.

Notwithstanding the increase of mean effective pressure at a given horse-power, the number of explosions to carry that horse-power is seen by the curves B_3 to increase with the speed. The need of this increase is at once explained, however, by glancing at the curves C_3 showing the effect upon frictional horse-power, where it is found that an increase of speed from 150 to 270 causes an increase in frictional horse-power from 1.19 to 3.39.

23. The curves may look somewhat irregular at first glance, but because of the difficulty generally experienced in determining frictional horse-power, it is believed that they are quite satisfactory. The narrow band in which all excepting the highest speed points are contained indicates unusual agreement, and indicates further that the amount of energy absorbed in friction under constant ignition, jacket temperature, and speed is nearly the same at all horse-powers.

24. Another interesting conclusion is evident from a consideration of the shape of the curves. Neglecting the two points at 6 and 8 horse-powers and at 300 revolutions per minute, this group has quite a decided bend in which the concavity is downward. Now since the frictional horse-power is made up of energy in which the two factors are resistance, and distance through

which the resistance is overcome, and since the amount of this energy is proportional to each of these factors, and since, further, the vertical scale of speed represents also the distance overcome, the departure from a straight line indicates a change in the resistance factor; in this case an increase. In other words, the increase in speed causes an increase of frictional horse-power because of an increase of resistance to motion, and because of an increase in the distance through which this resistance had to be overcome.

25. The decrease in mechanical efficiency resulting from this increase in speed is greater at low horse-powers than at high. The decrease due to the change from 150 to 300 revolutions per minute varying from 87 per cent. to 65 per cent. for the six horse-power, and from 62 per cent. to 34 per cent. for the two horse-power. The average decrease in mechanical efficiency, as shown by the three curves representing 2, 4 and 6 horse-power respectively, is 24 per cent. Assuming that the general trend of the curves may be represented approximately by a straight line, the relation between mechanical efficiency and revolutions per minute is represented by the following straight-line equation:

$$\text{F.H.P.} = \frac{\text{R.P.M.} - 97}{57}$$

in which F.H.P = Frictional horse-power,
R.P.M. = Revolutions per minute.

The increase in the amount of gas per fifteen minutes is due to two things: first, an increase in the number of explosions per minute to carry the different horse-powers; and, second, to an increase in the amount of gas per explosion, as is shown by dividing the amount of gas by the number of explosions at the highest and lowest speeds respectively.

26. A glance at the next curves, F_3, Fig. 218, indicates the effect of this speed change upon the standard gas per indicated horse-power, and shows that the increased speed is a decided disadvantage from the standpoint of cylinder performance. This means, as noted before, that though an increased speed resulted in an increase in mean effective pressure, this increase is not as great proportionally as the increase of gas admitted into the cylinder per explosion.

The increase in gas per indicated horse-power, and the decreased mechanical efficiency due to increased friction means, of course, a still more marked increase in the gas per brake horse-power per hour, which is illustrated by the curves G_8, Fig. 219. The increase in gas per brake horse-power per hour at the lower horse-powers is much more marked, as shown by the increased slant of the curves for the lower as compared with these at the higher powers.

27. By referring to the curves J_3 and K_3, Figs. 220 and 221, showing the jacket loss and the exhaust and radiation losses, it is seen that an increased speed produces a marked decrease in the heat absorbed by the jacket, but a greater increase in the amount exhausted and radiated. The effect upon these two factors of the accompanying increased frictional horse-power is probably that it tends to oppose the decrease in jacket loss and to exaggerate the exhaust and radiation losses.

Conclusions Concerning the Effect of Changes in Brake Horse-Power.

28. In a consideration of the curves showing the effect of changes in brake horse-power, which are designated by the subscript 4, it should be remembered that the characters on the curves now represent constant jacket temperature rather than constant horse-power as previously. It will be of interest first to note that an increase of power is attended by a decrease of mean effective pressure (A_4, Fig. 216). The increase in horse-power is secured, mainly, of course, by an increase in the explosions per minute. This increase of explosions per minute means a decrease in the scavenging effect of blank charges of air drawn through the engine, and in no small measure this decrease of mean effective pressure is probably due to the decreased scavenging. As before noted, a change in horse-power at constant notch of the mixing valve produces a change in the proportion of gas to air, and this doubtless has considerable effect on the change in mean effective pressure.

The effect of increased horse-power upon the frictional horse-power is to show an increase in friction from zero to about 3 horse-power, after which an increase in horse-power shows a considerable decrease in friction. This decrease in frictional horse-power for all of the higher horse-powers, and, in fact, from 2 horse-power up, taken in connection with the increase in brake horse-power, means a marked increase in mechanical efficiency.

The highest reached is 87 per cent. for the curve which represents the 200-degree jacket temperature (C_4, Fig. 217).

29. Since the frictional horse-power is made up of two factors, resistance and the distance through which the resistance is overcome, and since the speed or distance passed over in this series is constant, this change in frictional horse-power must be due to a change in the resistance.

The factors that probably tend to increase the resistance are the increased pressure on bearings and the increased time that it is applied. The principal factor that it is thought may decrease the resistance is the decrease in piston friction, due to a higher temperature of the cylinder lubricant, because of, first, its increased time of contact with heated gases; second, the decreased contact with cool air due to fewer blank charges; and, third, due to the cylinder lubricant being the highway through which passes a greater amount of heat to the jacket wall as the horse-power increases.

Since all of the factors at constant speed and ignition that go to make up friction is seen to be plainly subordinate to the jacket temperature, as shown by the curves under that variable, it is suggested that the decrease of friction due to increased horse-power is due mainly to the supposed increase in the temperature of the cylinder lubricant.

30. The curves showing the relation between the horse-power and the standard gas per indicated horse-power per hour, show that on the average the best performance is at 6 horse-power. Any change above or below this power shows an increase in gas consumption. From a consideration of the gas per brake horse-power hour, it at once appears that the increase in mechanical efficiency with an increase in horse-power is so great as to cause a continual improvement in the gas per brake horse-power per hour as the horse-power is increased. It thus turns out that the point of maximum efficiency based upon indicated horse-power is at 6, while from the standpoint of brake horse-power, its highest efficiency is found to be at the highest horse-power that the engine will carry.

From curves J_4 and K_4 it is seen in general that an increase in horse-power produces an increase in percentage of heat absorbed by the jacket, and a decrease in the heat exhausted and radiated. It is surprising, however, that these changes are both very much more marked at high than at low-jacket temperature.

Summary of Conclusions.

31. Ratio of gas to air series:

I. At a given notch of the mixing valve a change in horse-power causes a change in the ratio of gas to air.

II. The effect of a given change in the position of the mixing valve upon the ratio of gas to air is much more marked at the lower than at the higher notches.

III. The notch at which the gas valve is set is an important factor in the gas economy of the engine.

IV. A change in the notch of the gas valve has a marked influence upon the mean effective pressure, the extent and character of which is different at different horse-powers.

V. On an average the engine runs with the greatest economy at notch 3½, and an increase in horse-power necessitates a slight decrease in the notch position to secure the best economy.

32. Point of ignition series:

I. The point of ignition has a marked influence upon the mean effective pressure.

II. The highest mean effective pressure is secured by an ignition at a point designated as between normal and late, and nearer the former than the latter.

III. An increase of horse-power calls for a retarding of the point of ignition to secure a maximum mean effective pressure.

IV. The engine runs with the least amount of friction and the highest mechanical efficiency with the point of ignition between " normal " and " late."

V. From the standpoint of the brake horse-power, the lowest gas consumption and the highest thermal efficiency are secured with the late ignition.

33. Jacket temperature series:

I. At all horse-powers excepting the highest, an increase in jacket temperature is accompanied by a decrease in the mean effective pressure.

II. The increase in the jacket temperature from 90 degrees to 200 degrees results in a decrease of frictional horse-power from 3.88 to 2.61, or a net change of 1.27 horse-power. This results in an increase in mechanical efficiency from 57.3 per cent. to 66.1 per cent., or a net gain of 8.9 per cent.

III. The increase in jacket temperature causes an increase in the gas per indicated horse-power per hour from 15.5 cubic feet to 16.4, or a net increase of 1.27 cubic feet.

IV. The increase in jacket temperature is so beneficial from a mechanical standpoint in decreased friction as to cause a decrease in the gas per brake horse-power per hour from 28.86 to 26.17, or a decrease of 2.69 cubic feet.

V. The change in gas consumptions noted in III., due to a change in jacket temperature from 90 degrees to 200 degrees, results in a change in thermal efficiency based upon indicated horse-power from 17.38 to 16.06, a decrease of 1.32 per cent., and based upon brake horse-power from 9.76 to 10.75, an increase of about 1 per cent.

VI. The increase in jacket temperature considerably effects the per cent. of heat absorbed by the jacket and the per cent. exhausted and radiated. The effect on these factors is different at different horse-powers, and in brief is as follows: The increase in temperature at first causes an increase in the jacket loss and a decrease in the exhaust and radiation loss. In a general way, however, the increase in jacket temperature causes a decrease in jacket and an increase in exhaust and radiation losses.

34. Speed series:

I. An increase in speed results in an increase in the amount of gas per explosion, an increase in the mean effective pressure, and an increase in the explosions per minute at a constant brake horse-power.

II. The increase in gas per explosion is greater proportionally than the increase in mean effective pressure, and therefore results in an increase in the gas per indicated horse-power per hour, and a corresponding decrease in the thermal efficiency based upon gas per indicated horse-power per hour.

III. The increase speed from 150 to 300 revolutions per minute causes an increase in frictional horse-power from 1.19 to 3.39, or a net increase of 2.20, and on the average a decrease in mechanical efficiency of 24.8 per cent.

IV. The increase in frictional horse-power with increased speed is due mainly to the increased distance through which the frictional resistances are overcome, but in part to a slight increase in the resistances.

V. The increase in speed results in an increase in the gas per brake horse-power per hour, and a corresponding decrease in the thermal efficiency based upon brake horse-power. The reasons for this may be found in II. and III. above. These changes in gas consumption and in efficiency are much more marked at low than at high horse-powers, because of the much lower mechanical efficiency at the lower horse-powers.

VI. The increase in speed caused a marked decrease in the per cent. of heat absorbed by the jacket, and an increase in the per cent. exhausted and radiated.

35. Brake horse-power series:

I. An increase in brake horse-power from 0 to 10 causes a decrease in mean effective pressure from 93.86 to 82.29, or a decrease of 11.57 pounds.

II. An increase in brake horse-power causes at first a slight increase in the frictional horse-powers, and then a considerable decrease, which effect is more marked at high than at low jacket temperature.

III. The increase in brake horse-power from 2 to 10 causes an average increase in mechanical efficiency from 36.67 to 78.55, or a gain of 41.88 per cent.

IV. From the standpoint of the indicated horse-power, the lowest gas consumption and the highest thermal efficiency is neither at the highest or lowest horse-power, but at a point about .6 of the maximum.

V. For the same factors as mentioned in IV. from a brake horse-power standpoint, the best results are secured at the maximum horse-power of the engine.

VI. An increase in horse-power causes an increase in the jacket loss and a decrease in the exhaust and radiation losses. This change is more marked at high than at low jacket temperature.

36. In general:

I. From the standpoint of the indicated horse-power, the lowest gas consumption and the highest thermal efficiency are secured under the following conditons: Ignition between normal and late, jacket temperature, the lowest used, or 90 degrees; speed, the lowest tried, or 150 revolutions per minute; brake horse-power, at about .6 the normal capacity of the engine.

II. From the practical standpoint of gas economy and thermal efficiency based upon brake horse-power, the frictional horse-power is an exceedingly important factor, being in many cases sufficient to more than counterbalance decided thermal disadvantages. The lowest frictional horse-power, and the highest mechanical efficiency are secured with late ignition, high jacket temperature, low speed, and the highest horse-powers available under the conditions thus defined.

III. The importance of friction as a factor in realizing high thermal efficiency based upon brake horse-power, is emphasized by the fact that the highest efficiency is secured under substantially the same conditions as specified in II. for obtaining the least amount of friction and the highest mechanical efficiency.

Suggestions for Future Investigations.

37. It is to be regretted that inadequate facilities and pressure of other duties have made it impossible to give this investigation such attention as would have resulted in securing complete data for all the tests involving all the factors suggested, and in addition that of varying degrees of compression. It is expected, however, that the investigation will be continued, and it is hoped that other investigators will be encouraged to take up the problem and make a more complete and satisfactory solution than is here recorded, and also that many, in discussing this paper, will take a part in making suggestions as to the proper method of arranging and conducting such series of tests.

For such an investigation the following points are noted: It should be easily possible on the engine under investigation to secure and to observe with ease and accuracy, and through a wide range, changes in the following factors: speed, load, jacket temperature, proportion of gas to air, point of ignition, and degree of compression.

Observations should include factors for determining all efficiencies, both mechanical and thermal, all horse-powers—brake, indicated, and frictional—all gas consumptions, all heat distributions, all air consumptions, the various temperatures, and steadiness and certainty of action. The engine should be fitted with at least two types of governors, and with cylinders of different proportions of length to diameter.

These series of tests should be run on an engine of comparatively small size, then repeated on an engine of medium size, and again on one of the largest size available.

With an investigaton taken up on this line and conscientiously carried through, we should have a basis for formulating a theory of the gas engine which would furnish important lines of guidance for future development, the need for which is very great, and the like of which in the steam-engineering field we have been waiting for years, and in many particulars are still waiting, to secure.

DISCUSSION.

Prof. W. F. M. Goss.—Members of the Society will be interested in knowing that this paper is the last piece of work done by Professor Robertson before his departure for China to take up work under the International Board of the Young Men's Christian Association. This mission is among the educated classes of China, who are anxious to learn of the western world and wish to take up science and technology under western teachers, the ultimate purpose of all the instruction being to lead them gradually to an understanding of the principles of the Christian religion. In accepting the responsibilities of such a mission, I know that Professor Robertson has yielded to desires and inspirations which have long been strong within him, and I imagine that the example of his devotion will not fail to inspire others with interest in his work.

It is to be regretted that the proof of this paper could not have had the benefit of its author's scrutiny. In the absence of Professor Robertson, and in conformity with his wish, the proof-reading fell upon me, but I have not attempted to do more than to harmonize certain statements contained in the original paper with certain suggestions of the Publication Committee regarding the presentation of diagrams and tabulated results.

Finally, concerning the merits of the paper itself, I can testify to the long and very careful research which it represents. So far as I know, no analysis of the performance of an individual engine has ever been made so thorough as that of the Otto gas engine, the results of which are here presented. Professor Robertson's discussion of engine friction and of the factors which influence its value is, I think, entirely unique and satisfactory. While numerical measures, and even percentage values may be different for engines of different powers, yet the causes which are here shown to exert themselves will always exist.

No. 992.*

SOME DATA ON HOISTING HOOKS.

BY JOHN L. BACON, CHICAGO, ILL.
(Junior Member of the Society.)

1. The following are some results obtained from experiments which had in view a comparison of the strengths of hooks bent out of round stock, and hooks shaped according to Towne's formula, and also the effect of case hardening, or carbonizing, upon the strength of the above hooks. No attempt was made at mathematical analysis, the object being experimental data.

2. The general shape of the hooks tested is shown in Fig. 223. The eyes were welded, and pains were taken to have the lower curved parts of the hooks to be compared, alike as near as possible.

3. One of the conclusions drawn from the experiments was, that if the hook was properly shaped between the points A and B, Fig. 223, the shaping of the rest of the hook had very little to do with the strength; the shaping of the rest of the hook having more to do with the "hang" than the strength. Of course the critical part for strength lies at about the point C, the shape of the lower part merely determining the point at which the load will be applied. All of the hooks tested failed, either by bending or breaking, at about C.

4. When testing, working conditions were reproduced as nearly as possible. The hook was suspended by a loop of round iron run through the eye, the ends of the loop being gripped in the upper jaws of the testing machine.

5. A long link of round iron was put over the hook and through the lower head of the machine and a round bar passed through the lower end of the link under the head. This arrangement left the hook free to adjust itself to the strain in all directions.

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

6. Some of the samples were case-hardened or carbonized. These were heated with granulated raw bone. The $\frac{5}{8}$-inch hooks were hot for about 8 hours and the $1\frac{1}{4}$-inch hook for about 9 hours. The depth of penetration of carbon, or thickness of the carbonized coating of the mild steel was about $\frac{1}{16}$ of an inch.

7. The $\frac{5}{8}$-inch hooks were all made from one bar of mild steel and both $1\frac{1}{4}$-inch hooks were made from one bar.

8. In the following table the word "carbonized" is used to

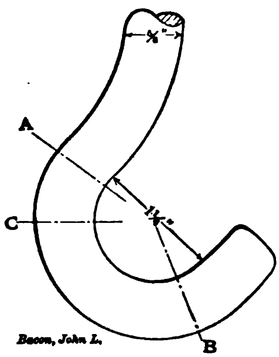


FIG. 223.

designate the hooks which were treated as described above. Those marked simply "carbonized" were allowed to cool in the box in which they were heated; those marked "annealed" were afterward annealed, and the ones marked "hardened" were hardened in the usual way.

9. Following are the more important data from the experiments :

Mark.	Kind of Hook.	Size of Stock.	Bend Started at	Max. Load.		T. S. of Bar.
				Bent.	Broke.	
		Inches.				
4	Plain..............................	$\frac{5}{8}$	2500	3000		62,150
5	Plain..............................	$\frac{5}{8}$	2400	3300		"
8	Plain—Carbonized and Hardened.....	$\frac{5}{8}$	4000		4200	"
1A	Plain—Carbonized and Annealed.....	$\frac{5}{8}$	2750		2900	"
2A	Plain—Carbonized and Annealed.....	$\frac{5}{8}$	2600	3200		"
2A	2A—Bent into Shape and Hardened..	$\frac{5}{8}$	5000		5200	"
X	Carbonized and Hardened—Towne's Shape, Fig. 2.	$\frac{5}{8}$			3000	"
XX	Carbonized—Towne's Shape..........	$\frac{5}{8}$	2800		3200	"
-X	Towne's Shape—Untreated...........	$\frac{5}{8}$	3000	3500		"
C	Plain—Carbonized and Annealed....	$1\frac{1}{4}$	9000		13500	
T	Towne's Shape—Untreated...........	$1\frac{1}{4}$	6000	13000		

All of the tested hooks were made in the shops and the testing was done in the laboratories of Lewis Institute.

10. Figs. 224 and 225 give the dimensions of the flattened hooks. These hooks were made to conform as nearly as practical to Towne's formulæ. The other hooks, bent into shape without any flattening, had the same inside curve as the flattened hooks.

11. The flattened hooks all gave way by compressing the metal shown by the shaded area. This was easily determined, as the scale at this point cracked off and was undisturbed on the other parts.

12. All of the hooks which failed by bending stood a much

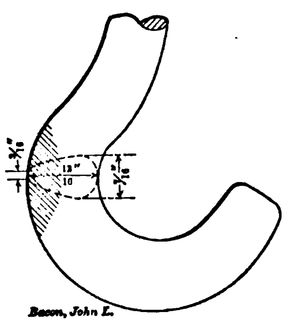


FIG. 224.

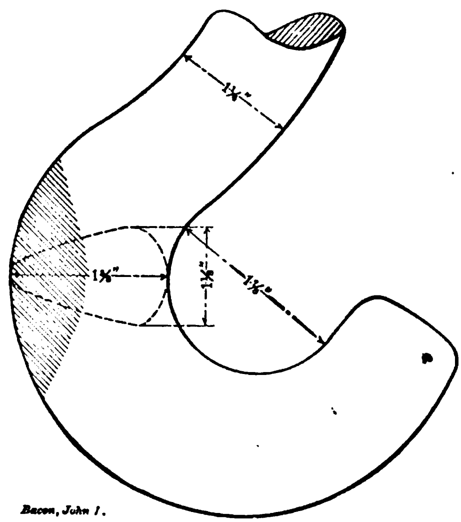


FIG. 225.

higher load after the bend started; or, in other words, the hooks would stand a heavier load after they were partially straightened out, due, probably to the fact that as the hook straightened, the leverage of the load was decreased.

13. The above data would seem to indicate that a hook made from round iron and carbonized, is about as strong as the same shaped hook flattened according to Towne's formulæ, while a plain hook carbonized and hardened is from 40 per cent. to 50 per cent. stronger than either of the other two.

14. The following may prove interesting as showing that the untreated hooks stand greater strains after they start to open. The detail report of the test on hook T was as follows: Very slight opening at 6,000 lbs. load; open scant $\frac{1}{32}$ of an inch at 8,000 lbs.; strong $\frac{1}{32}$ of an inch at 9,000 lbs.; $\frac{1}{16}$ of an inch

at 10,000 lbs.; $\frac{1}{8}$ of an inch at 11,000 lbs.; would not sustain load of 12,000 lbs. any length of time, and opened rapidly at 13,000 lbs.

15. After the above test, and without disturbing the hook in the testing machine, a load of 13,000 lbs. was applied. The hook carried this load without showing any signs of further opening for about 15 days. At the end of that time the load was increased and the hook straightened almost to a right angle, after which it held a load of 15,500 lbs.

DISCUSSION.

Mr. H. R. Towne.—The experiments reported by Mr. Bacon are an interesting addition to the scanty literature on the subjects of hooks, and especially so as tending to settle the question of preference between the round and flattened forms of cross-section.

As Mr. Bacon uses the "Towne formula" as a basis of comparison, it seems expedient to reproduce that formula herewith. It was originally published in a "Treatise on Cranes," published by me in 1883, and as therein stated (page 91) the formulæ were based on a long and thorough investigation of the matter, which included numerous tests of hooks of various forms and sizes. The formulæ thus determined were as follows, the measurements all being expressed in inches, and the symbol $\triangle$ being used to indicate the nominal capacity of the hook in tons of 2,000 pounds:

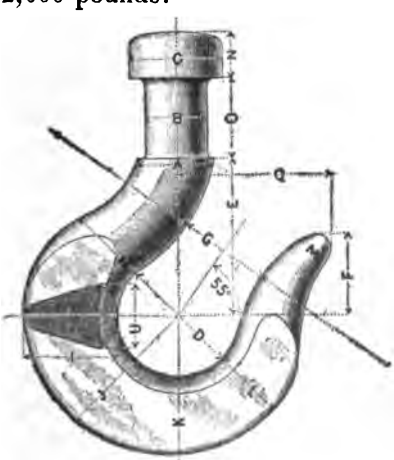


Fig. 226.

$$
\begin{aligned}
D &= .5\ \triangle + 1.25 \\
E &= .64\ \triangle + 1.60 \\
F &= .33\ \triangle + .85 \\
G &= .75\ D \\
O &= .363\ \triangle + .66 \\
Q &= .64\ \triangle + 1.60
\end{aligned}
$$

$$
\begin{aligned}
H &= 1.08A \\
I &= 1.33A \\
J &= 1.20A \\
K &= 1.13A \\
L &= 1.05A \\
M &= .50A \\
N &= .85B - .16 \\
U &= .866A
\end{aligned}
$$

The dimensions A are necessarily based upon the ordinary merchant sizes of round iron. The sizes which it has been found best to select are the following:

Capacity of Hook	$\frac{1}{8}$,	$\frac{1}{4}$,	$\frac{1}{2}$,	1,	$1\frac{1}{2}$,	2,	3,	4,	5,	6,	8,	10 tons.
Dimension A . . .	$\frac{5}{8}$,	$\frac{11}{16}$,	$\frac{3}{4}$,	$1\frac{1}{16}$,	$1\frac{1}{4}$,	$1\frac{3}{8}$,	$1\frac{3}{4}$,	2,	$2\frac{1}{4}$,	$2\frac{1}{2}$,	$2\frac{7}{8}$,	$3\frac{1}{4}$ inches.

The formulæ which give the sections of the hook at the several points are all expressed in terms of A, and can therefore readily be ascertained by reference to the foregoing scale.

Mr. Bacon's tests indicate that, under like conditions of material, the flattened hook will carry a 20-per-cent. greater load than the round hook before beginning to open. Referring to his table, we find that Nos. 4 and 5 (round form) began to bend or open at a mean stress of 2,450 pounds and No. $-X$ ("Towne" form) at a stress of 3,000 pounds, the latter being 22 per cent. greater than the former. It is to be regretted that Mr. Bacon did not make more experiments which would admit of a direct comparison of the results obtained with the two different forms of hook. Those which he reports, show clearly that carbonizing and hardening raise the elastic limit and increase the load required to cause the hook to begin to open, but this advantage is neutralized, in my judgment, by the accompanying fact that carbonizing and hardening tend greatly to diminish, or even to obliterate, the margin between the bending and breaking points.

In the original publication above referred to I made the following statement:

"Experiment has shown that hooks made according to the above formulæ will give way first by opening of the jaw, which, however, will not occur except with a load much in excess of the nominal capacity of the hook. This yielding of the hook when overloaded becomes a source of safety, as it constitutes a signal of danger which cannot easily be overlooked, and which must proceed to a considerable length before rupture will occur and the load be dropped. A comparison of these hooks with most of those in ordinary use will show that the latter are, as a rule, badly proportioned, and frequently dangerously weak."

Mr. Bacon's tests confirm this argument. In No. $-X$ bending began at 3,000 pounds and the hook yielded at 3,500, a margin of 16 per cent.; in No. T bending began at 6,000 pounds and the hook yielded at 13,000 pounds, a margin of 116 per cent.; while in most of the other tests, with carbonized hooks, the margin between initial bending and final yielding or breaking is only 5 to 10 per cent. So far as they go these tests are conclusive that a hook should not be made of high carbon metal, and that the desirable metal is a ductile one, which will permit the hook to bend through a considerable angle before the danger point is reached.

The "Towne" formulæ were intended to cover only sizes up to 10 tons—that is, those ordinarily made in large quantities and in which economy of material is important.

Mr. F. A. Waldron.—It has been my privilege, for over fifteen years, to have been connected with the manufacturing end of this hook proposition, in the Works of the Yale & Towne Manufacturing Co., and, after careful observation of hooks, made of different materials and in different forms, I am, at present, not only theoretically convinced, but practically persuaded that the only proper material from which hooks can be made and be perfectly reliable is of a high-grade puddled iron, such as Burden's best, and that the form should be in accordance with the Towne formula. It has also been my privilege, during the past nine years, to observe the different uses and abuses accorded to hooks in general use. A summary of these observations may be of interest in connection with Mr. Bacon's paper:

1. To produce a reliable hook a material must be used which will stand the abuses of the average drop-forging process, the principal danger in which is in the manipulation required in pointing and bending.

2. A hook is no stronger than its weakest point; and while a bar of mild steel may have a higher tensile strength, and, further, a steel hook, properly made, may stand from 25 to 50 per cent. greater load than a wrought-iron hook, it does not follow that the steel hook is better and more reliable than the iron hook.

3. About a year and a half ago, after a series of laboratory tests, the Yale & Towne Manufacturing Co., at my suggestion, decided to change from iron to steel, in view of the fact that steel costs only about one-half as much as the best grades of iron, and, further, that tests of steel hooks showed so much greater strength; therefore, I felt justified in recommending this change. After some thousands of the steel hooks had been made, however, we found that many of them broke from crystallization while being manipulated in the shop, and that others

broke on our block-testing machine, on account of the unevenness of the steel and its inability to stand the heat and manipulation under the drop-hammer, all of these defects being invisible. A large number of these steel hooks were scrapped, and the steel purchased for this purpose was used on other work where life and limb were not at stake.

4. Since then, and at present, all hooks are made from high-grade wrought-iron, and no further trouble has been experienced, probably for the following reasons:

(*a*) Iron will stand more abuse, in the fire and under the hammer, than any steel yet made.

(*b*) Defective bars of iron are easily detected, either from longitudinal seams in the grain, or from the opening up of imperfectly rolled seams during the processes of pointing or bending.

(*c*) If over-heated or under-heated, the surface defects known as "cold short" and "red short" cracks appear in the bending, and the hook is condemned before it has had a chance to fail under actual service.

5. A further result of my experience is that one of the greatest strains on hooks of the smaller sizes, say, from $\frac{1}{4}$ to 2 tons' capacity, is due to the usage which these hooks receive in many shops. Blocks have been returned to us with the hooks opened out, and, upon inquiry, we have found that the load had been lifted by just catching the point of the hook under the sling chain or ropes.

6. Iron hooks, made in accordance with the Towne formula, have been returned to us having serious surface defects, which, through oversight, had passed inspection and reached the customer. Invariably these hooks, upon their return, have been tested to destruction, and none of them, in spite of these defects, have broken at less than $2\frac{1}{2}$ times the working load, while we have had several steel hooks break at the working load, without a moment's warning.

7. Any treatment given to a steel hook, by carbonizing, annealing, or case-hardening, tends to aggravate any invisible defects which may exist, with the exception of crystallization. The latter, undoubtedly, is helped by proper annealing.

An iron hook is less affected than a steel hook by any of the above treatments, with the possible exception of case-hardening, which tends to produce a brittleness in the iron, while it may increase to a slight extent its carrying capacity. If, however, a hook is made of the proper proportions, the subsequent annealing or carbonizing, as proved by actual test, may show an increase in the factor of safety, but such subsequent treatments (except annealing) tend to produce brittleness and an additional risk to the operator.

FIG. 227.

A is an end view of a *steel* hook which broke under nominal load.

B is an iron hook which broke under 2½ times nominal load, notwithstanding the flaw shown by the dark area.

The steel hook snapped off suddenly, and nearly killed the operator who was testing it. The iron hook opened up gradually before breaking.

This is not an isolated case, but is a sample of other breakages.

The conclusion I have reached, therefore (based on my experience), is that the best hook for all-around use, for reliability, safety, and to withstand the abuse to which hooks are subject, is a drop-forged hook, proportioned according to the Towne formula, and made of high-grade wrought-iron.

We have yet to learn of one of these hooks breaking during the manufacturing processes, or developing a defect which cannot readily be detected before it leaves the shop, or failing in service under its normal load.

Mr. Gus. C. Henning.—While we have had very much better papers on the strength of hooks, I do not think we have ever had any paper quite as good as this short one on what to use and what not to use in hooks. We find here that carbonized and hardened hooks are no good. They stand up to the load within a few pounds, and then snap suddenly. There is no material so little affected by heat treatment as first-class wrought-iron. There is no material worse under those conditions, when it is subjected to varying temperatures and when the material is of varying dimensions, than steel of almost any kind, and when it is carbonized, hardened and annealed, nobody knows what it may be when finished. On the other hand, test a piece of iron and it will be practically known what that iron will be when it has been forged, because it is changed so little by the treatment. We find here that the plain hooks untreated break at loads considerably above the bending point. That point is the yield point for that material—nothing else. Now that is what we want to know. On the other hand, the carbonized and hardened hooks break at only 200 or 150 pounds above that load under which they begin to show the slightest sign of bending. In that respect this paper is invaluable. It says, "Never think of using a carbonized and hardened hook or one of heat-treated steel," because the men who treat it may consider themselves experts, but they do not know what the hook is until they have tested it, because the material becomes different according to its thickness from the point to the shank; and I think the paper is invaluable because it tells you clearly not to use anything but plain, first-quality wrought-iron hooks.

Mr. A. E. Johnson.—What I was going to say has been so fully covered by Mr. Waldron that I can add almost nothing except that at the Yale & Towne Manufacturing Co. we found the yielding point of their hooks was from 60 to 70 per cent. of the ultimate. In other words, the hook was that much of a safety valve. The principal thing that I wanted to present was that in such machines as cranes and hoisting devices there should be a safety valve, and there cannot be a better one than the hook, made so that the opening will give every one ample warning, because it is right before everyones eyes.

Mr. Oberlin Smith.—I would like to ask gentlemen who have had experience in designing section hooks whether the I-beam section has been tried, and why it has been abandoned, as it would seem evident that more strength would be obtained with material in such a shape than in the triangular shape.

Mr. McGeorge.—I notice quite a number of manufacturers are using cast-steel hooks. I would like to ask whether anyone has had any experience with them.

Mr. F. A. Waldron.—Replying to the questions of Messrs. McGeorge and Smith, the cast-steel hooks have been tested by us, and we have found that their cost is prohibitive and the quality was not any better than wrought-iron. Steel hook castings have shown very good results in yielding, but we do not consider them reliable, as the defects are invisible.

In reference to the I-beam section for use on hooks, I think it might be somewhat lighter in weight for the same strength, but the manipulation in manufacturing would not be as simple as for the present form, and it might further, in shops where ropes were used as slings, tend to fray the rope where it came in contact with the sharp edges.

Mr. Henning.—Tests have been made on such hooks by Professor von Bach, and he has determined that the differences in the quality of the material are the essential difficulties, because the metal is of different thickness at all points. The treatment is always an unknown quantity. The edges are not of a large radius, but must have sharp corners. In regard to the castings, the hooks are always of such small dimensions that it cannot be furnished without blowholes or cavities. At present I think it is unsafe to use cast-steel hooks.

*Mr. J. L. Bacon.**—I thank the gentlemen who have added such valuable matter to the paper under discussion. As indicated by the title, the paper was presented merely as *data* on an interesting subject.

I know that Mr. Towne and Mr. Waldron must have had vastly more experience with hooks than I ever expect to have, and I would not gainsay any of their opinions. I do, however, take issue with Mr. Waldron on one point. He makes the statement that "iron will stand more abuse, in the fire and under the hammer, than any steel yet made."

Iron will stand more abuse in the fire than steel, but unless you compare an exceptionally fine grade of iron with a poor grade of steel, I think the advantage is with the steel, when it comes to abuse under the hammer. It is taken for granted that Mr. Waldron is speaking of low carbon, mild, or soft steel.

It is not uncommon to see a blacksmith use a bar of iron by mistake for a bar of mild steel when making a forging. He

* Author's Closure under the Rules.

works the bar as he would a bar of steel, and his remarks when he sees the result, while very interesting, would hardly make a dignified appearance in the *Transactions*.

Wrought iron, from its nature, has minute slag seams running all through it, while steel, if properly made, should be homogeneous. Each of the seams in the iron is a source of weakness, and is liable to start a crack when hammered. Steel not having these seams does not run this risk of splitting.

What seems to be the principle obstacle to the use of mild steel is carelessness in selection. When a man wants steel for ordinary forging, he is content to order "mild" or "soft" steel and let it go at that, and yet the same man would not think of ordering "tool" steel without specifying in some way the quality of temper.

Now, one bar of "mild" steel may be a tough, low carbon, even steel that will stand any amount of hammering and abuse, and the next bar will be so high in carbon that it will snap off like tool steel.

I plead for a more careful grading of the much abused "mild" bar steel.

All the hooks mentioned in the paper were made of steel. A few iron hooks were tested, but the results are not given.

No. 993.*

STRAINS PRODUCED BY EXCESSIVE TIGHTENING OF NUTS.†

BY A. BEMENT, CHICAGO, ILL.
(Member of the Society.)

1. In the design of machinery, ultimate strength, elastic limit and deflection of parts usually receive careful attention; but with prevailing practice and methods of erecting machinery in final

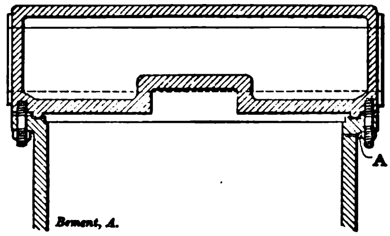


Fig. 228.

place, there is but little assurance that damage may not be caused by ignorance or carelessness on the part of the erecting crew, owing to excessive tightening of nuts and screws, which may, and often does, result in straining bolts and parts beyond their elastic limit. There appears to be no rule in general use for the guidance of the men who perform the work of machinery erection, and it seems usually to be their desire to make things as tight as possible. The natural result is that elastic limits are often exceeded or that breakages may even occur.

2. The accompanying figure represents one end of a cylinder of a vertical Corliss engine, with the valves located in the cylin-

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions.*

† For further references on this subject, see *Transactions* as follows:

No. 450, vol. xii., p. 781: "Some Experiments with a Screw Bolt." James McBride.

der head. With this example the nuts of the studs, holding the head to the flange, were screwed up so tight that it resulted in over-strain finding relief in a crack, which developed in the wall of the cylinder just under the flange, as shown at *A*. A tongue on the head fitted into a groove in the face of the cylinder flange; packing for making the joint was compressed in this groove by the pressure exerted by the tongue; when the packing was fully compressed, further strain owing to over-tightening of the bolts resulted in the fracture at *A*, which manifested itself some weeks after the joint had been made up. The crack extended part way around the cylinder, but did not result in entire rupture. It appears that when sufficient relief had been secured that the crack ceased to extend notwithstanding the presence of the steam pressure.

Other examples could be given showing the result of over-straining of bolts and parts of machinery, but this will serve the purpose.

It is the hope that this brief paper may serve to call attention to a matter which is probably more serious than is generally realized.

DISCUSSION.

Mr. Oberlin Smith.—The obvious way in erecting standard machinery would be to have the wrenches of a good length and do the final tightening either with a weight or spring pressure, or by the hardest pull a man could give. Of course, with ordinary men, the maximum could be found in all cases. Certain men whose personal equation was known could be put at pulling and practical trouble would be at an end. It is desirable that there should be a systematic way of doing this tightening up, as the evil pointed out in the paper is quite apt to occur when least expected. Before determining just the moment that should be exerted at the end of the wrench, more should be known about what pressure can be put on a nut. Of course, we cannot calculate it simply by the pitch of the screw and the yield-point of the metal, etc., because the friction of nuts varies so much. I think great attention should be paid to determining the nut friction, due to certain kinds of faces on the nut and its size and shape. This could all be determined by simple experiments, and the other matter of wrench length, certainly important, should be paid attention to.

Mr. Fred F. Miller.—This idea of having a length of wrench adapted to every size of nut looks very well at first glance; that is, that we can decide how much pull a man can exert, and then proportion the length of the wrench so that he can just tighten the nut to the exact point contemplated by the designer. But the way that works out in practice is that a man who handles such wrenches must exert his maximum strength on every nut. He has to tighten every nut by using the maximum force that he can exert; the men soon tire of that and will get a piece of gas pipe and put it on the wrench. You cannot get along without the personal equation. You have got to have men who know by their own judgment when the nut is tight enough, or you must instruct them. For instance, take two bolts of the same size; they should manifestly be tightened to the same stress, and if we adopt this idea of the proper length of wrench then the same force will be applied to each; but in some cases I am satisfied that with the same force applied to the wrench one bolt may be stressed four times as much as the other. So much depends upon the fit of the thread in the nut, the frictional resistance in the thread, and of the face of the nut on the surface on which it rests. A skilled man can tell by the "feel" of the wrench whether the force is being used in one way or another; I can, and I think anybody accustomed to it can tell whether the force is being applied to tightening the bolt or is being used up in frictional resistance.

Mr. Gus. C. Henning.—This author is not speaking of stresses, but of strains. He does not speak of the strength of the material. He is speaking about the elastic limit, which he uses instead of the term yield-point. In a boiler we do not care how strong the material is as long as we know that it will not yield under the loads. Prof. Bach, our authority, has written a paper on his investigations on the same thing. He has determined the stresses and the strain, and he has given many instances of ruptures of that sort. The way to avoid this—but it costs a little more money—is to use a lot of little bolts. It is when you use few bolts and the material begins to bend between the bolts that you cannot get it tight and then you will give an extra pull on the wrench which will cause the trouble. It is not because of the stress, but because of the strain. This gentleman is quite right in talking of strains and stresses. Simply use more bolts, and you will not have trouble.

Mr. McGeorge.—May I give you some personal reminiscences. When I was a young man we had an agent who supplied machinery in Java, and he insisted that no bolts smaller than ⅝-inch should go in. The reason was this; he said you get a nigger on the end of the wrench and he will break every bolt that you put in smaller than that.

Mr. Henning.—I want to point out that that is one safety factor. The breaking of a ⅝-inch bolt will not hurt anything at all, and you cannot crack the tank in the way it is shown here. That builder should have used ½-inch bolts and let the nigger break them as often as he wanted to. Which costs more—144 bolts or one tank? .

Mr. Crane.—We might contrive to make a wrench with two pieces, and have a scale registering the strength and let it tip up automatically when the strength required was reached.

Mr. A. E. Johnson.—As to the question of "many small bolts" versus "fewer large ones," it would seem that work such as flanges bolted together needed the first arrangement as a safety-valve to save flanges, while large parts of heavy frames, such as planer posts or riveter frames can be better and cheaper fastened by the latter arrangement. We believe in always using the largest bolts practical to be tightened by the longest practical wrenches, *e.g.*, in the case of a band tightened frictionally around some other part, the pinching bolt should of course have about the same area as the rest of the band—although we have seen cases where such bolts had less than one tenth this area. In arranging the framing for the 12-inch disappearing carriages we desired to place our 2-inch bolts as near together as possible and have the fork wrench to be used clear the corner of the adjacent heads, but found no data in the wrench catalogues enabling us to determine this distance with certainty. If these manufacturers would add a column in tables of standard wrenches, stating against each end of each drop forging just how near the largest bolts for which this end is milled could be spaced, it would help us on such occasions.

Mr. Saunders.—I have found that bolts very often strained to almost the breaking point are allowed to go out that way and break when they go into service. We have had some trouble with them, in fact, more than anywhere else.

Mr. Oberlin Smith.—I have found that one of the worst evils with the men is that you cannot govern them as to how hard they will strike the wrenches. Mr. Miller has said that the only remedy is to have a man who knows how hard to pull. I suppose most of the men in this room know how hard to pull, and I do not suppose any of us would break anything, but when we are away the workmen will do it on the sly, and use gaspipe or anything else. In general machine work the problem is a difficult one. But I was speaking of a standardized machine where routine work can be done over and over; the men can be taught to use the proper tools. It may be that a special weighing wrench, as suggested by one of the speakers, would be a good thing.

Mr. Henning.—My statements were based upon my experience when I was the foreman of a machine shop and boiler works in Baltimore, where we were having considerable trouble of this sort. They were using flat heads $1\frac{1}{4}$ inches thick, and 1-inch bolts, and every other week one would break. I simply used a thinner material and nothing larger than $\frac{5}{8}$-inch bolts, and thereafter we never had one come back broken. The flange was cast iron, and nobody ever pulled very hard. From that time on we never had any more trouble.

One very important feature of this discussion has been overlooked, and that is the question of spot facing. At the present time a deplorable condition exists in the commercial articles, due to the fact that spot facing in a great many cases, is neglected. I have seen bolts loosen up in the rims and hubs of fly wheels and driving pulleys, due to the fact that the bolts were set against the rough surface of the casting and there was absolutely no parallelism between the faces of the nut and the head of the bolt. This also exists on extra heavy steam pipe work, and in order to insure the best results the back as well as the face of the flange should be spot faced or trued off. The unevenness of these surfaces tend to produce greater strains in the bolt than any other single cause.

Mr. Sweeney.—The remark of the last speaker is true but it applies more to the effect on the bolt than it does to the flange. After some experience in these matters, the form of the joint in this paper appeals to us as one in which probably the bolts were too strong. Where the surface of the flanges fit up solid, it brings in a different condition from that where the flange overhangs the joint, as it does in the illustration. Usually people put too many bolts in such a joint and when the personal equation comes in to screw it up, if the man cannot find a piece of gas pipe he usually makes it convenient to sit down, brace his feet against something which offers resistence, which is another way of arriving at the gas pipe effect, and breaking things.

I have found it much the safer plan to put in bolts which would break before the casting would break, in a joint of this construction.

Mr. Henning.—That is because a big bolt is so far away from the flange that you can get a big wrench on it.

*Mr. A. Bement.**—The cylinder in question is 38 inches in diameter, studs 1.5 inches in diameter, spaced 5 inches between centers. Wall of cylinder 2 inches thick; thickness of flange, 2.25 inches.

Another engine of the same design erected by the same maker soon after the one mentioned, also gave trouble. Its cylinder diameter is 46 inches. Diameter of studs 1.5, spaced 5 inches between centers. Thickness of cylinder wall 2.25 inches, and thickness of flange 2.5 inches. With this cylinder, overstrain found relief by springing the head; throwing the valve chambers out of line, which resulted in the valves sticking, breaking of valve arms, etc. This condition was followed by some of the studs breaking, but the castings did not rupture. This would indicate that the smaller cylinder wall was the weakest point, while with the large one, the studs were the weaker feature.

Between breaking a cylinder or the studs, the latter is, of course, to be preferred, but a cylinder head joint with broken studs is not a desirable condition. As much damage may be caused by the breaking of a bolt as by failure of a casting, for example—excessive strain in setting up follower bolts caused one of them to break, and part of the bolt leaving its position while the engine was in motion resulted in knocking off not only the head, but the top of the cylinder.

There is danger in small bolts, because a man is liable to exert his whole strength in tightening, regardless of their size; or use a hammer on the wrench. With the cylinder head joint, least opportunity for damage might exist with small bolts; but with the joint between follower and piston, with metal to metal, liberal strength in the bolts would be on the side of safety.

It would be desirable to have some means of determining when the proper tension on a bolt was secured, but this is a difficult proposition. In the absence of such means, it is altogether probable that much damage could readily be avoided by the exercise of a little judgment.

Such troubles are probably the outgrowth of a feeling that when a machine is designed and made in the shop, that the en-

* Authors' Closure, under the Rules.

gineering work is about done, and that its erection is rather a labor than an engineering problem. The result is that the foreman, instead of superintending the setting up of nuts and bolts, is often at rest in an easy chair smoking a cigar, while the men are lightening their labor with a sledge hammer and with no idea whether they are overstraining bolts or not. And if there is trouble, the blame is usually laid on the mechanics or laborers whom no one expects to possess any large degree of engineering judgment.

It should be said in the case of the two engines mentioned, that when the owners' engineers remade the joints, that troubles ceased.

No. 994.*

THE HOT WELL AS AN OIL EXTRACTOR.†

BY A. H. ELDREDGE, SO. ST. JOSEPH, MO.
(Member of the Society.)

1. Figs. 229 and 230 give the plan and cross-section of a hot-well that has been in successful operation during the past year.

The well is divided into three parts.

A the common discharge side for the steam condensers.

B the discharge side for one steam condenser.

C the hot side, or pump side.

2. The operation of the well is as follows: The bulk of the condensing water enters at *A* and overflows, to a cistern, at *D*. The water from a single jet condenser enters *B*. The water from this condenser comes from an engine that runs continuously nearly the entire year. Its temperature is kept between 125 degrees and 160 degrees Fahr. to favor the boiler feed temperatures, although at the expense of the vacuum, which runs from 20 inches to 24 inches.

The higher temperature also saves condensing water.

There are two outlets from *B*, one an underflow at *E* into *C*, and one an overflow at *F* into *A*. The overflow at *F* is 3 inches lower than the one at *D* to insure a free passage in and out of *B*.

3. The hot side, or pump suction side *C* is supplied from *B* through *E*. The temperature of this water is increased by returning to it, so far as possible, all steam drips, and pump, or other exhausts, raising its temperature to from 160 degrees to

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

† For further discussion on Oil Extraction consult *Transactions* as follows:
No. 678, vol. xvii., p. 295: "Oil Extraction."
No. 678, vol. xvii., p. 297: "Oil Filtration."
No. 810, vol. xx., p. 489: "Test of Oil Separators." F. L. Emory.

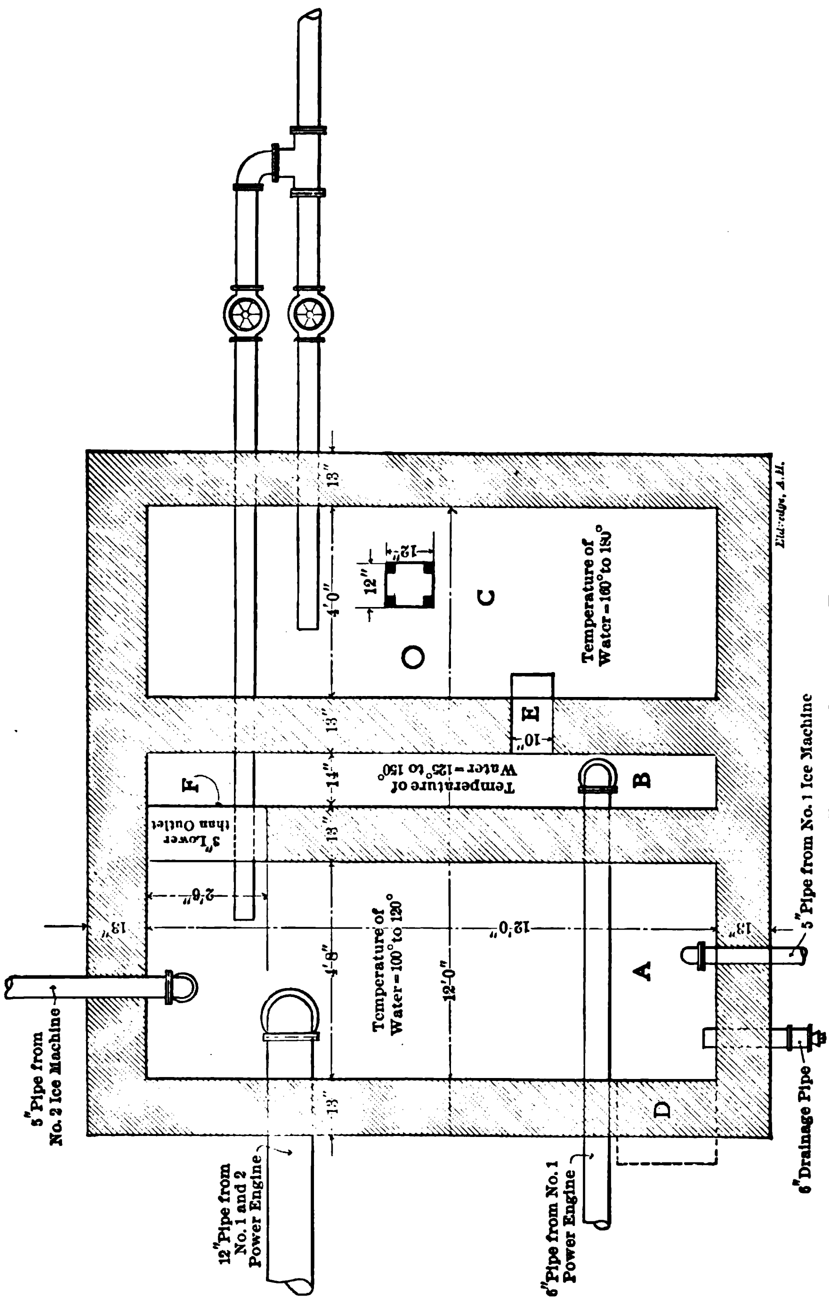


FIG. 229.—PLAN OF HOT WELL.

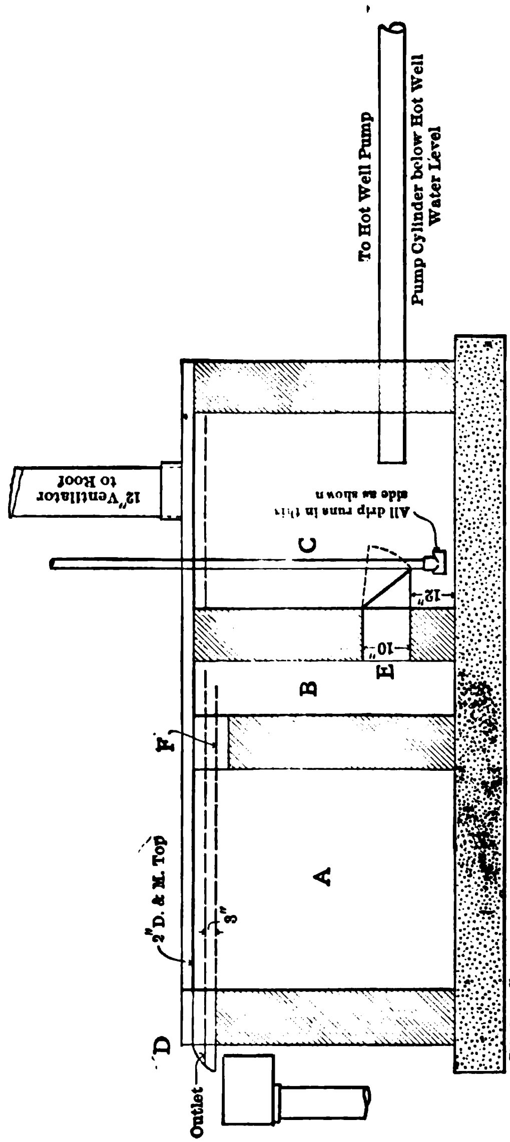


FIG. 280. SECTION OF HOT WELL.

180 degrees Fahr. This gives a good start for a desirable feed water temperature, and at the same time saves many traps, together with their accompanying troubles and expense, insuring the return of the various drips with their British thermal units to the boilers.

The only outlet from *C* is through the pump suction, and only such water enters *C* as is sufficient to supply the pump.

Should the water at any time be cut off from *B*, then the supply would come automatically from *A* through *F*.

The hot-well is provided with drain pipes in *A* and *C* for clean-out purposes.

Its Action as an Oil Separator.

4. The water enters *B* at a comparatively high temperature, and any oil in the water will rise rapidly to the surface, while the oil from but one condenser is all that has to be taken care of. At the same time the flow of the water from *B* to *C* is very slow, giving ample time for the oil to rise to the surface and pass off through the overflow *F*.

5. Over 3,000 horse-power of boilers, at one of Swift & Company's plant, are fed from this hot-well, and no sign of oil has been found in any of the boilers or their connections.

The water from *C* has also been chemically analyzed a number of times, and but the slightest trace of oil has ever been found. The trace found was undoubtedly due to the oil coming in through a pump exhaust, and has in no way affected the practical working of the hot-well.

DISCUSSION.

Mr. A. A. Cary.—This method of eliminating oil from water condensed from exhaust steam, described by Mr. Eldredge, is one with which I have experimented, but only a fair degree of success.

My experiments were made a number of years ago, and I described the hot-well I used in the May, 1897, number of the *Engineering Magazine.*

In this hot-well, I constructed only two compartments, or the apparatus might be considered as one large rectangular brick tank, with a dividing wall running across its centre as shown in

Fig. 231, which presents a plan-view and a vertical cross-sectional view of the device.

By referring to these views, it will be seen that the oil-laden water from the condenser is introduced into the first compartment through the pipe *A*.

As the water is discharged from this pipe, it strikes the top of

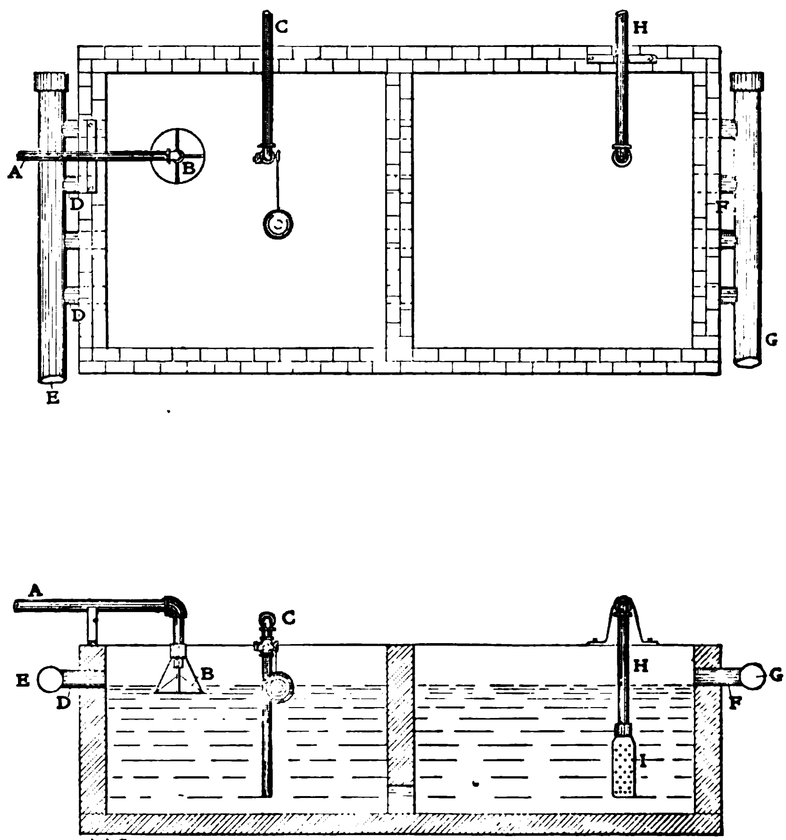


Fig. 231.

a cone, *B*, which prevents the flowing stream from impinging forcibly upon the surface of the water in the tank, and causes it to flow down the sides of this cone on to the upper surface.

As the solid wall dividing this tank into parts has its only openings (into the other half of this tank) near its bottom, the water must flow from the first compartment into the second compartment through these lower orifices.

The purpose of this arrangement is to allow the oil contained in the water in the first compartment to float to its surface, while the water from which it has separated descends to the bottom of the tank and then passes into the second compartment.

A second pipe, *B*, having a cock with a ball-float on its end, admits water from the city supply (when needed) to keep the level of the surface of this water slightly above the overflow outlets, *D*, which are connected to an outside sewer-pipe, *E*, which in turn conducts the troublesome oil away from the tank.

Experiment proved that notwithstanding this arrangement to separate the oil from the water in the first compartment, a certain amount of oil passed into the second compartment, and in order to get rid of this oil as it floated to the surface, a second system of overflow pipes had to be arranged as shown at *F*, and these overflows were connected into the second sewer-pipe *G*.

The feed-water for the boiler was taken from this second compartment through the suction-pipe, *H*, which was provided with a strainer *I* at its lower end.

Probably the most difficult condition found in oil-charged water, when we desire to separate the oil, is when the oil exists in an emulsified form. It is very well known that oil and water will not mix directly, but we know equally well that oil will spread itself over the surface of the water, and a thin film will cling to this surface most tenaciously.

When water is broken up into a large number of little globules (such as small rain drops, or the spray from a hose), and when oil is present in the water at the time of its sub-division, this oil is apt to coat the surface of each one of these little globules (like the skin which covers an orange) and retain its position there after the water falls back into a solid mass, and then we have an oil emulsion such as I have referred to, and a microscope, properly manipulated, will show this condition as existing.

When oil exists in water in this form, it is no easy problem to separate it by ordinary commercial means, and its separation by any method of flotation is entirely out of the question. It was this fact that led me to place a cone directly beneath the discharge-pipe from the condenser.

Experiment in this case taught me that by allowing the water to fall from a distance and strike the surface of the water, the falling water was split up, and a churning action occurred in the tank, which resulted in an emulsion of the oil and water. Sub-merging the end of the discharge-pipe in the water helped matters somewhat, but caused a churning action, so I finally placed the cone directly beneath the discharge outlet, which caused the water to slide gently down the incline onto the surface of the water (the lower end of the cone being entirely submerged), and this allowed much of the oil to float itself upon the upper surface of the water, from whence it was discharged through the sewer openings.

*Mr. Eldredge.**—The suggestion of the sliding plane, as outlined by Mr. Cary, could be easily used in connection with the hot-well as presented by the author.

That the hot-well as presented worked satisfactorily with the Western or Missouri Valley water, there is no doubt. Possibly with Eastern waters, where there is less scale-forming matter, the small amount of oil which might be carried over from the hot-well would cause trouble. It would be interesting to know the result of experiments along this line in the East.

---

* Author's Closure, under the Rules.

No. 995.*

POSITIVE GOVERNOR DRIVES FOR CORLISS ENGINES.†

BY A. H. ELDREDGE, SO. ST. JOSEPH, MO.
(Member of the Society.)

1. WHILE visiting a Corliss engine works recently, the proprietor, a member of the A. S. M. E., asked the writer for any information he might have on positive governor drives for Corliss engines. Hence this paper.

In *Machinery*, March, 1899, was an article by the writer on "The Corliss Governor and Fly Wheel Accidents," in which was tabulated some of the Corliss engine accidents that had occurred, attributable to the governor belt. At the same time it was recommended that belts be replaced by positive drives. Since then he has equipped three large power engines and two large ice machines with positive drives with gratifying results.

Power Engine Drives.

2. The engines were cross-compound condensing engines, fitted with rope drives, and driving three two-phase alternating current generators. The sizes of the engines and generators were as follows:

1—14 and 26x36	driving	1—180 K. W.	Generator
1—16 and 30x36	"	1—240 K. W.	"
1—21 and 40x42	"	1—500 K. W.	"

The engine speed was 90 revolutions per minute. The generators are so arranged that any two or all three can be run in parallel.

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV., of the *Transactions*.

† For further discussion on Governors consult *Transactions* as follows:
No. 409, vol. xi., p. 1081: "A Governor for Steam Engines." Jesse M. Smith.
No. 640, vol. xvi., p. 729: "A New Shaft Governor." E. J. Armstrong.
No. 714, vol. xviii., p. 290: "Steam-Engine Governors." F. H. Ball.

3. Before putting on the positive drive the governor belts were a continual source of trouble and anxiety. It was impossible to keep the oil from the belts. New belts, endless belts, oil flanges, etc., were things of a day. It was difficult to cut two generators in together, and still more so to cut three generators in together, while it was no uncommon thing for the circuit breakers to fly out due to poor engine regulation. This trouble has ceased since the positive governor drives were installed. The generators can be easily and quickly cut in together, while they adjust themselves much more quickly to their proportionate load. The engineers and oilers appreciate fully the improved working conditions of the engines and generators. The gears are cut steel gears and run very quietly. The only trouble experienced in over a year's run was on the large engine. There was no floor stand at A, Fig. 232. This allowed considerable spring between these gears so that the pitch circle did not remain constant. It was first greater and then smaller with each revolution of the shaft. This kept the governor dancing in unison with the revolutions of the engine, first up then down about $\frac{3}{16}$ of an inch on the governor spindle. A good floor stand and bearing was put in at A, Fig. 232, since which the governor runs steadily, changing only with the load.

Ice Machine Drives.

4. Two Ball ice machines, with cross-compound steam cylinders 26 inches and 50 inches × 48 inches, and two compressor cylinders each 21 inches × 48 inches, have been fitted with cut steel sprockets and "Morse Rocker Joint" chain. Here again there was always trouble with an oily, slack governor belt. Since the chain drives were substituted for the belt drives the machines run more steadily at all speeds from 17 to 75 revolutions per minute.

6. The chain drive has some points of advantage over the geared drive. (See Fig. 233.) It is cheaper to install. It is not affected by any slackness, or wear, of the main bearing. It requires less attention and runs more quietly. It has not, however, as neat an appearance as a geared drive.

The chain drive could be easily applied to throttling governors. A greasy belt on a throttling engine, a runaway engine and a dead engineer, is the tale of a recent accident at the R. T. Davis Mills at St. Joseph, Missouri.

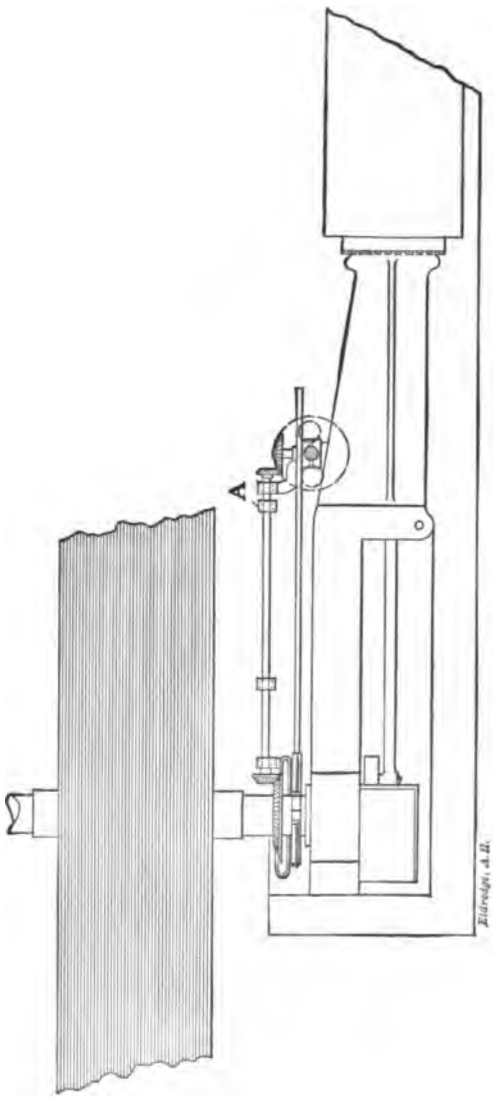


FIG. 232.

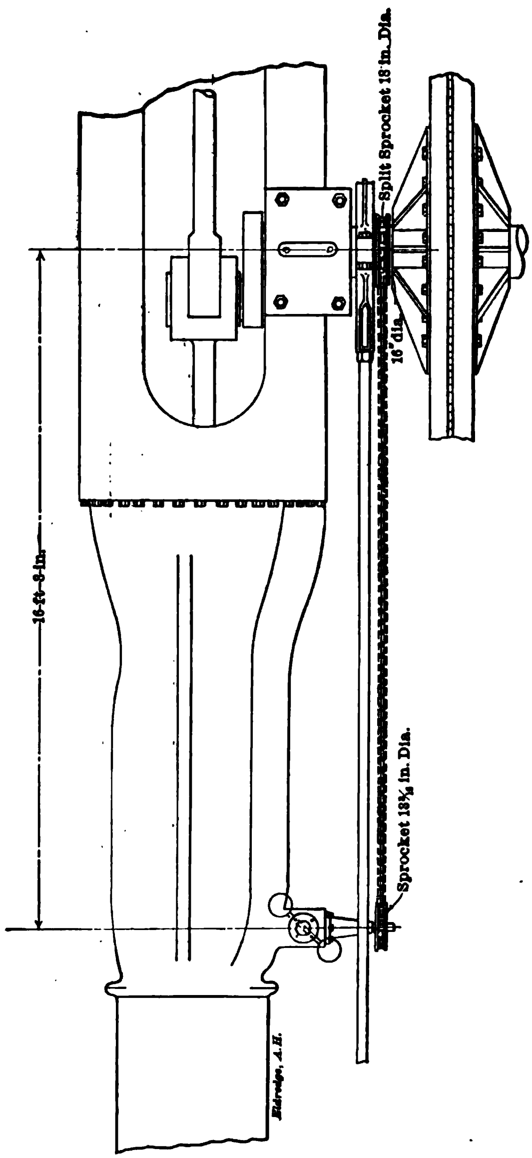

Split Sprocket 18 in. Dia.
16" dia.
16-ft-8-in.
Sprocket 18⅛ in. Dia.
Eldredge, A.H.

FIG 283.

Most Corliss engine builders advertise their so-called safety stop, either man, or mechanically operated; but in spite of the stops the engines frequently fail to stop until after the wreck.

The danger is not where a belt breaks and allows the safety device to work, but where the oily belt slips and does not keep the governor up to speed, allowing a longer range of cut-off than is necessary to care for the load, in which case the engine soon speeds up to the danger line.

There is no excuse for the governor belt. The consulting engineer could soon relegate it to the past if he chose.

DISCUSSION.

Mr. A. A. Cary.—Mr. Eldredge's statement that "there is no excuse for the governor belt" will hardly be accepted by many of us, I am sure.

It is true that this belt is a source of trouble in some plants, but this trouble can generally be accounted for by the presence of a careless, a dirty or an incompetent engineer, who does not take proper care of his belt. The substitutes presented by Mr. Eldredge have been used in not a few plants, and have also been a source of trouble.

Where there are sudden changes of load in plants where close regulation is required, the slipping governor belt can frequently be replaced by another belt which will not allow objectionable slipping, the new belt being either wider, or, being made to run over pulleys of larger diameter, or else over pulleys with wooden faces.

The best substitute offered by Mr. Eldredge is the gear arrangement, which is utilized in the Brown engine, but I know of cases where the teeth of these gears have broken, and other troubles have resulted due to wear.

Such gears should be enclosed in dust-tight cases, and be constantly lubricated with clean oil. The teeth should be carefully and accurately formed in a gear planer, and they should be constantly run on their pitch lines. The boxes holding them in place should be rigidly and accurately secured in proper position, and no spring should be allowed in the shaft, as Mr. Eldredge has stated.

There are few of the gear-governor drives I have seen which have not at some time had, at least, a certain amount of cotton waste run between their teeth, while many have had more resisting material dropped into their "bite."

I have also found, frequently, the gear shafts running loosely in their boxes, and further, I have noticed much noise emitted from the gears, indicating lost motion between the teeth.

As far as the chain application is concerned, I have had experience with engine appliances driven by this means, and found that constant running stretched the chain, causing it to flap or vibrate considerably when sudden loads were applied, and this motion, at times, threw the chain off the sprockets, thus making it a very dangerous appliance.

In view of these experiences, I am inclined to give my preference to the belt drive, believing that nothing of this kind can be made "fool-proof," and I think that many here will agree with me.

Mr. McGeorge.—I think the Renold Chain Company or the Morse Chain Company will guarantee chains against all stretching. I *know* that the *Morse* will absolutely guarantee against stretching, and I believe the Renold will, too.

*Mr. Eldredge.**—Having read Mr. Cary's discussion carefully, I still believe, after fifteen years of designing, building and handling both Corliss and high-speed engines that "There is no excuse for the governor belt," and will further add, or other friction drives.

I have long heard of the incompetent engineer, but I have some sympathy for the competent man, whose machine works twenty-four hours a day, six days a week, with but a brief shut-down on Sunday, and who is unable to overcome the faulty design of his engine and properly protect and care for his governor belt.

A chain, or gear drive, can be easily cased in and protected against waste, or harder substances getting into "the bite" due to carelessness or other causes. But what would be the result of such an accident? Simply a shut-down. It is not possible to have the governor lag behind the speed of the engine, as with the slipping belt drive, and allow a runaway engine.

It would be interesting to know the style of chain used in the drives referred to by Mr. Cary.

None of the three drives is perfect. It is a matter of deciding

---

* Author's Closure, under the Rules.

which is to be preferred: one which will adjust faster and permit a runaway, or one that, costing a little more money will make a runaway impossible.

Present practice, as could easily be cited, is answering in favor of the positive governor drive.

No. 996.*

FITS AND FITTING.

AN INVESTIGATION OF RECENT PRACTICE IN FORCING, SHRINKING, DRIVING AND RUNNING FITS, AND LIMITS FOR LIMIT GAUGES.

BY STANLEY H. MOORE, KANSAS CITY, MO.
(Junior Member of the Society).

1. In his endeavor to obtain for presentation to students reliable and definite information on this subject—matter which bore the semblance of systematic deduction—the author could but re-echo the sentiment of Professor Sweet's recent remark in reference to certain kinds of fitting. Professor Sweet says in part: "Mechanics trying to find out how much to allow for forced fits must, if they look up the literature on the subject, get pretty badly mixed."

The crude or working material which is the basis of this investigation is that which has been published during the last few years in the leading technical periodicals. The available matter was divided into two classes: that which bore the stamp of scientific investigation, and that which was submitted as the successful practice of some individual or concern. The representative instances of the former class are the excellent articles in vol. 22, *American Machinist*, by Professor Wetmore and Mr. T. C. Kelley. To the second class belongs by far the greater portion of the data investigated. This matter, at first seemingly hopelessly at variance with itself and somewhat chaotic in character, afforded, however, excellent material with which to work.

2. It is the purpose of this paper to explain in brief the method of procedure in the deduction of the resultant formulæ, representative curves and tabulated data. For the convenience of treatment the matter was divided into the following classes: Forcing

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV., of the *Transactions*.

Fits, Forcing Fit Pressures, Shrinking Fits, Driving Fits, Running Fits, and Limits for Limit Gauges. In order, in each individual case, to discover and ascertain the nature of a probable law, the data were transferred to rectangular co-ordinates where the curve was plotted, the ordinates representing the diameters in inches; the abscisses the allowances. The result of this first plotting was the deduction of an empirical formula for each individual case. For the purpose of comparison the curve for this formula was transferred to what was termed the Typical Diagram. In these typical diagrams such curves as were obviously wild and wide of the mark were omitted.

3. The next step, and one deemed necessary for the compilation of an accurate table of fit allowances, was the selection or construction—from the typical diagrams—of what were termed Representative Curves which would clearly indicate good practice. The choice of these representative curves, being largely a matter of judgment, is open to criticism; however, the selections were made with a view to securing a simple formula that would at once embody the essential features of good practice and omit nothing of importance. A careful examination of these curves, with due consideration as to the manner in which they were obtained, will, we think, justify the selection.

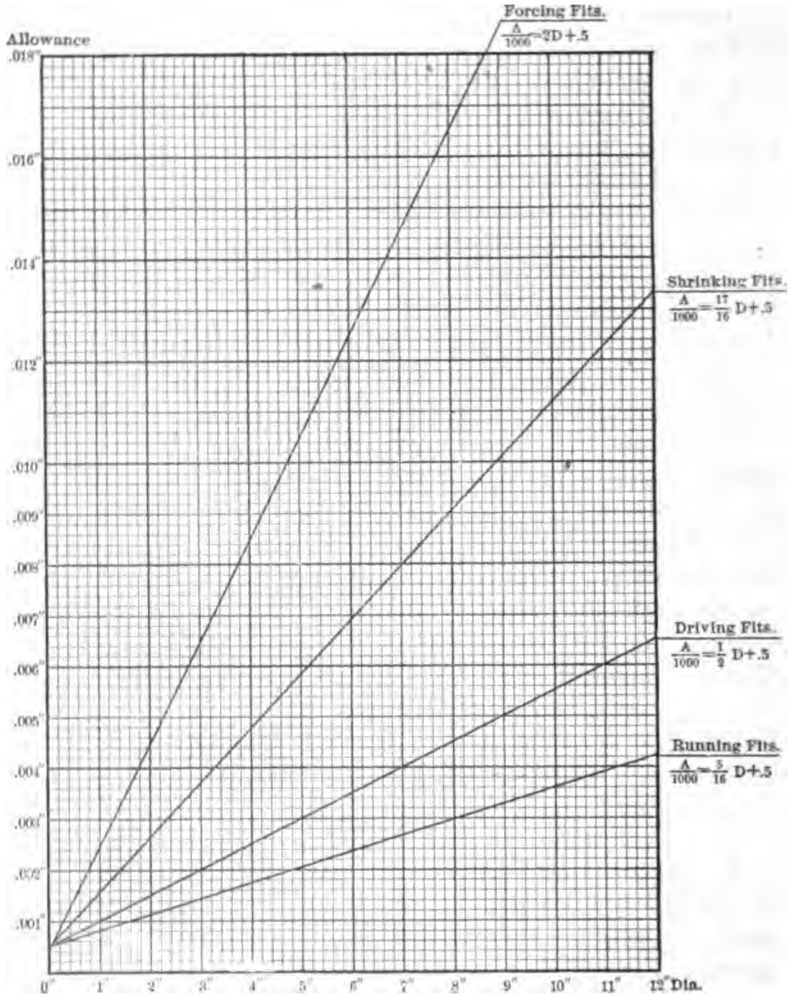
Turning our attention now to the several sub-divisions of the subject, we will discuss briefly the salient features of each.

Forcing Fits.

4. For the purpose of discussion, forcing fits may be defined as those machinery fits which require the use of some form of press, generally hydrostatic, to complete the assembling operation.

A study of the various curves of the typical diagram for forcing fits led to the selection of a Representative Curve whose formula contained a constant. This was considered desirable, especially on account of its influence on the smaller sizes. The formula selected for the Representative Curve for forcing fits was: $A = 2D + .5$; A = Allowance in thousandths of an inch, D = Diameter of the plug in inches.

5. Regarding the assembling process, or the manipulation of forcing fits, we find the following governing conditions: 1. The Allowance. This should never be so great as to prevent the stress from coming well within the elastic limit or the crushing strength of the materials employed. 2. The Surfaces. In gen-



REPRESENTATIVE CURVES FOR THE VARIOUS FITS. Moore, Stanley H.

FIG. 234.

eral we may say regarding the surfaces for this kind of fitting, that the best results are obtained when both surfaces are ground to fit gauges. The conditions, in some instances, render this impracticable; however, the surfaces of the pieces to be assembled should be as smooth as it is practical to make them. 3. The Lubrication. Linseed oil makes an excellent lubricant for assembling forcing fits. 4. The Alignment. It is important to start the plug accurately; so important is this that to secure an accurate alignment some engineers resort to the use of two diameters —each half the length of the fit—differing by but a few thousandths of an inch. The additional advantage of having to force the plug through but half the length of the fit, it is claimed, greatly reduces the maximum forcing fit pressure.

Forcing Fit Pressures.

6. Here the fixed conditions are generally the following: The materials employed; the nominal diameter; the length of the fit, and the thickness of the hub. With these conditions the pressure necessary to assemble a given forcing fit will vary, Mr. Kelley concludes after his experience with about eight hundred forcing fits on regular engine work:

(1) Directly as the area of the surface of the fit for a given diameter.

(2) Directly as the allowance—the difference in diameter between the plug and the bore.

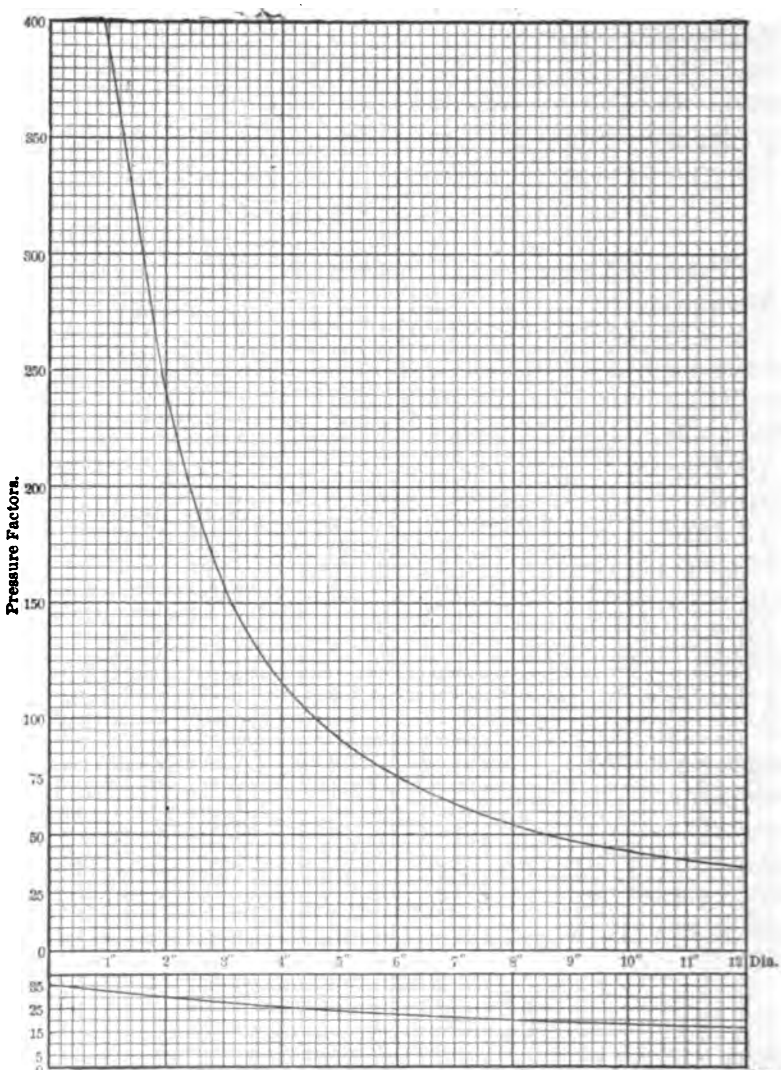
(3) As a function of the radial thickness of the hub.

(4) As the materials employed and the nature of the machined surfaces. The investigation for a pressure curve was undertaken on this basis—on the assumption that these conclusions are correct. After considerable work a simple equation for a Representative Pressure Curve was established. This equation gave essentially the results obtained by the use of Mr. Kelley's experimentally derived curve, and while possessing the advantage of mathematical deduction, it had the additional advantage of conforming to experience and becomes, therefore, thoroughly practical in its application.

7. The curve, an hyperbola whose equation is

$$PF = \frac{500}{D^{1.06}},$$

where PF is the Pressure Factor and D the nominal diameter of the fit, assumes the hub to be twice the diameter of the plug, the materials employed to be machinery steel plugs and cast iron hubs, and the machined surfaces to be practically true and free from tool marks. Should the hub diameter exceed twice that of the plug, the pressure, according to condition three, will be somewhat greater—the amount being obtained by the construction of another hyperbola. Should the materials employed be other than those which the curve assumes, the pressure, according to condition four, will again vary, necessitating the determination



FORCING FITS -- PRESSURE FACTOR CURVE. *Moore, Stanley H.*

FIG. 235.

of another value of PF. . . . The few values obtained from the meagre data relative to this particular point, seemed to indicate that a new value of PF might be obtained by multiplying PF directly by the ratio existing between the average value of the crushing strengths of the two new materials and the average value of the crushing strength of cast iron and machinery steel.

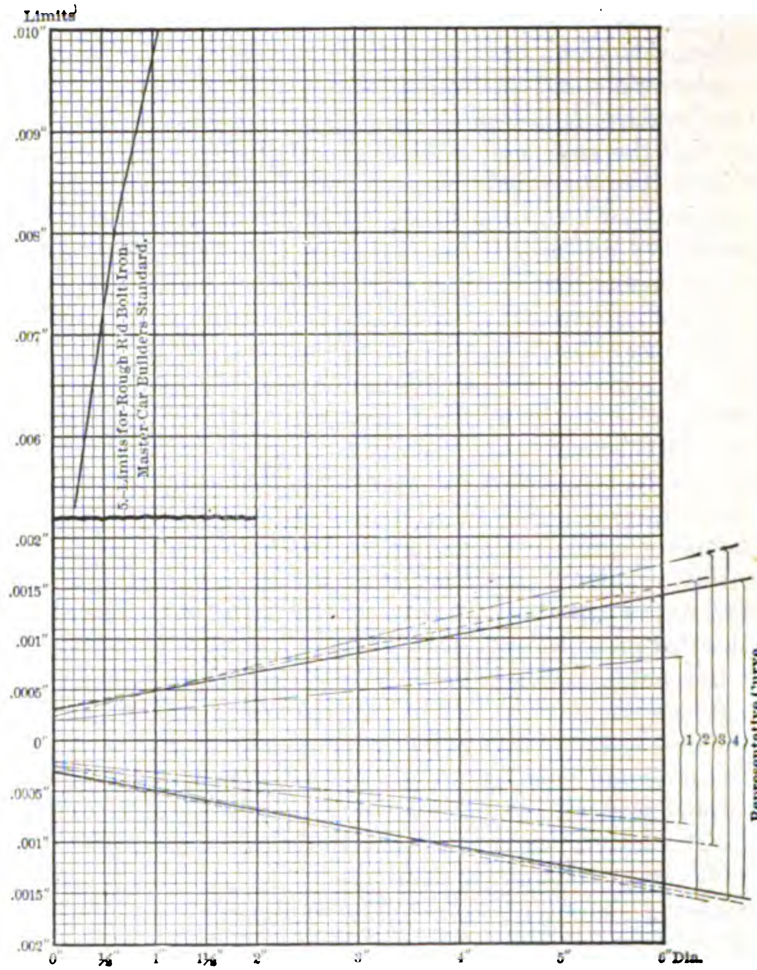
Moreover, the investigation disclosed the problem to be far too complicated to admit of any so simple a solution. The dearth of particular values and the incompleteness of the experiments leading to the above indication, were such as to influence the author to say that the statement is of no practical value. However, it may be well to state that the problem was first attacked on the assumption that a solution might be had from a comparison of the moduli of elasticity of the materials. This position was rendered untenable: first, because in materials such as cast iron which have no well defined elastic limit, the modulus decreases from a maximum near the beginning of the test; second, as some permanent deformation of the bore and plug generally results as a consequence of the assembling, the elastic limit of the material is obviously passed—this furnished a clew for attacking the problem with reference to the crushing strength. Then again the investigation proceeded with a treatment of the hub as a thick hollow cylinder under tension: were this assumption correct, the formulas of Professor Barlow and Merriman should be applicable and the tension on every concentric layer caused by the internal pressure, vary inversely as the square of its distance from the center. This position is faulty in that cast iron is not homogeneous in texture, is not incompressible, and when used for the material of cylinders of hydraulic presses the thicknesses which obtain are such that the stresses calculated by these formulas would postulate the use of steel to render them reasonably safe. This latter may not be a parallel case, as hydraulic cylinders are usually solid at one end.

In passing the author concludes that the influence which the use of different materials will have on the pressure may only be satisfactorily determined by experiment.

8. The tabulated values of PF from this curve will prove the more convenient for ready reference; however, the method of using the curve is as follows: Select the nominal diameter of the fit and follow its ordinate up to the curve; from this intersection follow horizontally to the left and read PF the pressure factor. The equation for the pressure is

$$\text{Pressure in Tons} = \frac{\text{Area of surface of fit} \times \text{Difference in dia. between plug and bore} \times PF}{2}$$

The result will be the pressure in tons required to force the plug home. A foreman may thus also easily determine whether or not his press is of sufficient capacity for the work in hand.



TYPICAL AND REPRESENTATIVE LIMITS DIAGRAM.

FIG. 236.

Shrinking Fits.

9. The Representative Curve chosen for shrinking fits was the one whose equation gave allowances which agreed with the standard adopted by the American Railway Master Mechanics' Association for locomotive wheel-center and tire gauges. The agreement is identical to the thousandth decimal place, this being the extent to which their standard is carried. The equation is $A = \frac{17}{16} D + .5$, $A =$ Allowance in thousandths of an inch. The allow-

ances obtained by the use of this formula while not excessive are sufficient to insure a tight fit, thus avoiding the danger of excessive shrinkage stresses, ofttimes deemed negligible, which are always additional to those incident to actual service. Taking the modulus of elasticity of steel at 30,000,000 the stress caused by this amount of shrinkage would be about 33,000 pounds per square inch, which is well within the elastic limit of machinery steel.

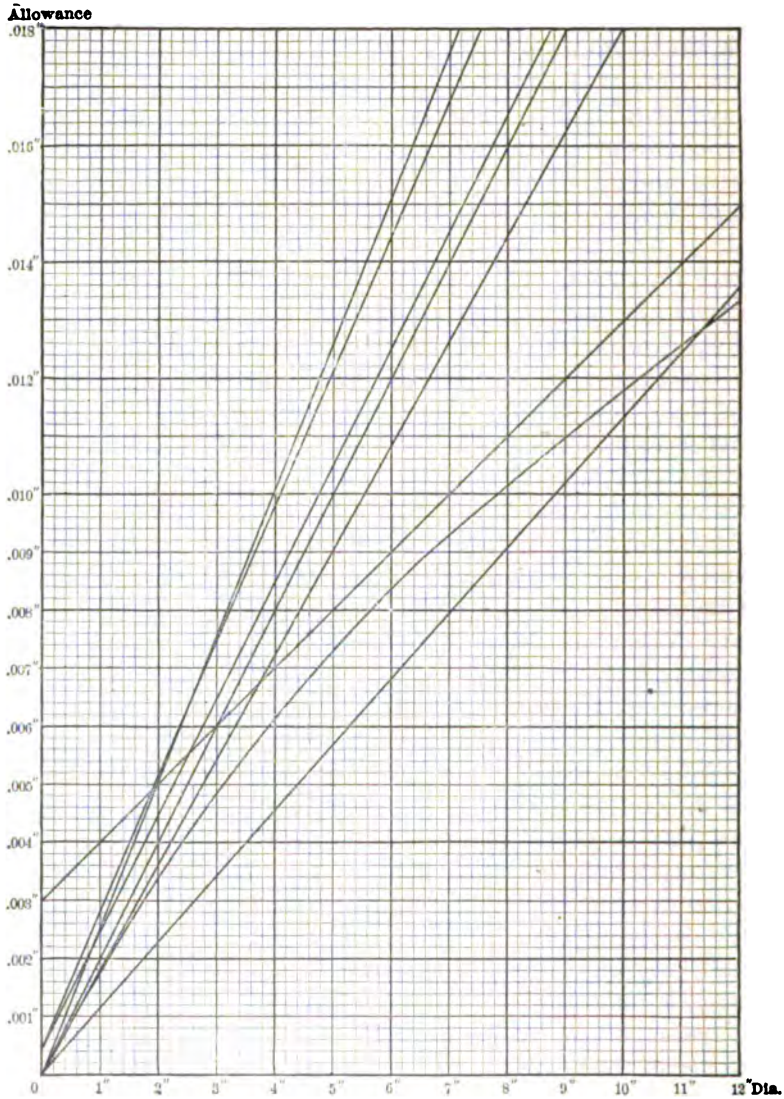
10. Considering this class of fitting with a view to obtaining the greatest resistance to tension and torsion, we discover that shrinking fits are far superior to forcing fits, they being, under like conditions, as Professor Wetmore has shown, uniformly about three times as tight both in tension and torsion. Experiments seem to indicate that in this class of fits the resistance to torsion increases more rapidly with the diameter than does the resistance to tension.

11. In the manipulation, good practice maintains that a piece should rarely be heated hotter than a very dull red heat—about 800 degrees Fahr.—and under no consideration to the scaling point. This temperature of necessity limits the fit allowance to something less than 700 degrees × .00000556 = .003892 per unit diameter for cast iron. It will be found upon an examination of the formula that the heating to this temperature is ample for the allowances given by the Representative Curve.

12. Regarding the process, better results will be obtained if the entire piece be heated slowly and uniformly instead of trying to hasten matters by "blazing up" through the bore. The latter practice is sometimes negative in its results; in cases permanently reducing the bore diameter instead of increasing it as desired, the expansion being inward instead of outward. In general, it may be said that this class of fitting requires more skill and experience in its manipulation than does force-fitting. Not only in the heating and assembling is this skill and experience necessary but in the cooling as well.

Driving Fits.

13. Very few data could be secured for this class of fitting, the inference being that this method of assembling is about obsolete. A field may still exist for such small work as the assembling of the smaller pins and cranks of valve gearing, where the formula



TYPICAL FORCING FIT DIAGRAM.

FIG. 237.

for the Representative Curve might be used to advantage when the fit is made with an arbor press or some kindred method. This formula might also be used for some classes of tight-keyed fits; however, the practice of driving home a plug by blows is too crude to be used except where no other method is available.

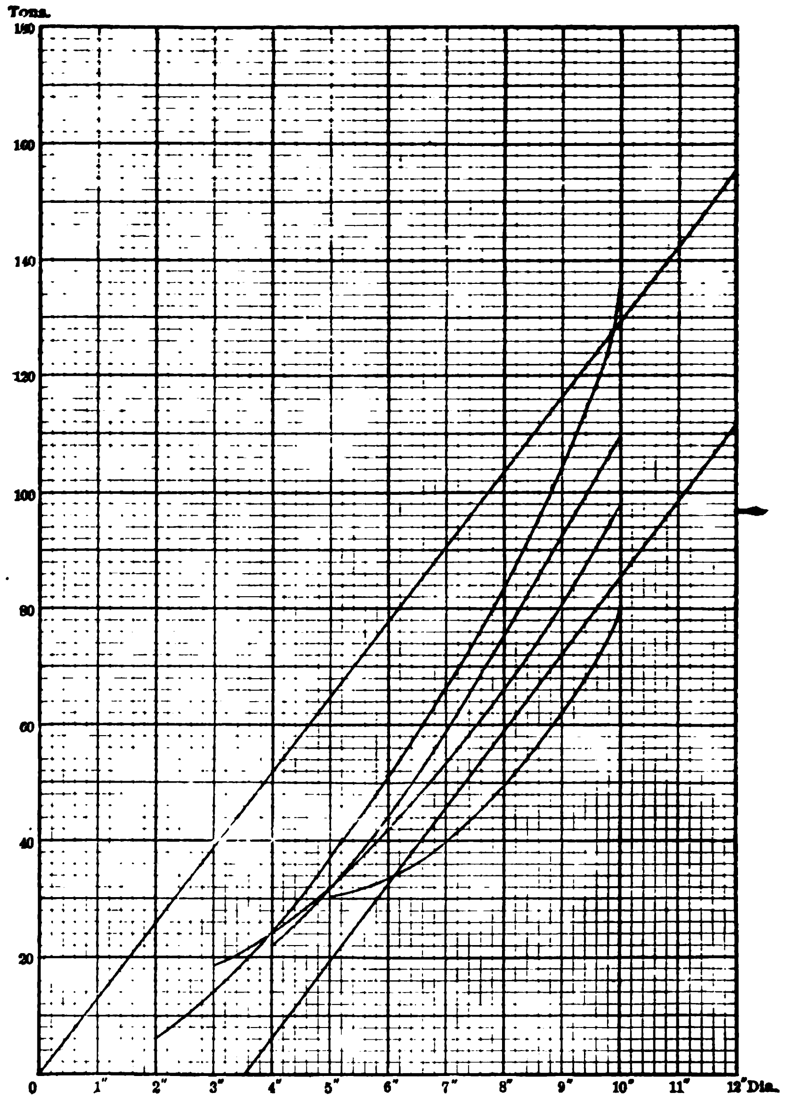
Our Representative Formula for this class of fitting is $A = \frac{1}{2} D + .5$, A = Allowance in thousandths of an inch.

Running Fits.

14. A running fit is designed to allow the surfaces in contact to move or revolve freely over each other. The more nearly the surfaces in contact approach perfection the better will be the fit; however, there should be a sufficient difference in diameter to admit of motion and lubrication. The difference in diameter to be allowed in any given fit depends upon the following conditions: the nature of the machined surfaces; the kind of metals in contact; the length of the fit and its diameter. The perfection of the fit, depending largely as it does upon the surfaces in contact, renders it imperative that they be smooth and true. When possible, on the smaller sizes, bored holes should always be reamed, as this not only insures a standard size but finishes the hole comparatively smooth and true.

15. The formula selected for the representative curve for running fits on machine tool, engine work and kindred practice was $A = \frac{5}{16} D + .5$, A = Allowance in thousandths of an inch. It will be remembered, of course, that in order to obtain the bore diameter the allowance should be added to the diameter of the shaft. For obvious reasons it was considered desirable that this formula contain a constant; it assumes the condition of the surfaces in contact to be similar to that obtained by the use of a reamer and the allowances will be found to fall slightly within the limits given by the representative curve on the limits diagram.

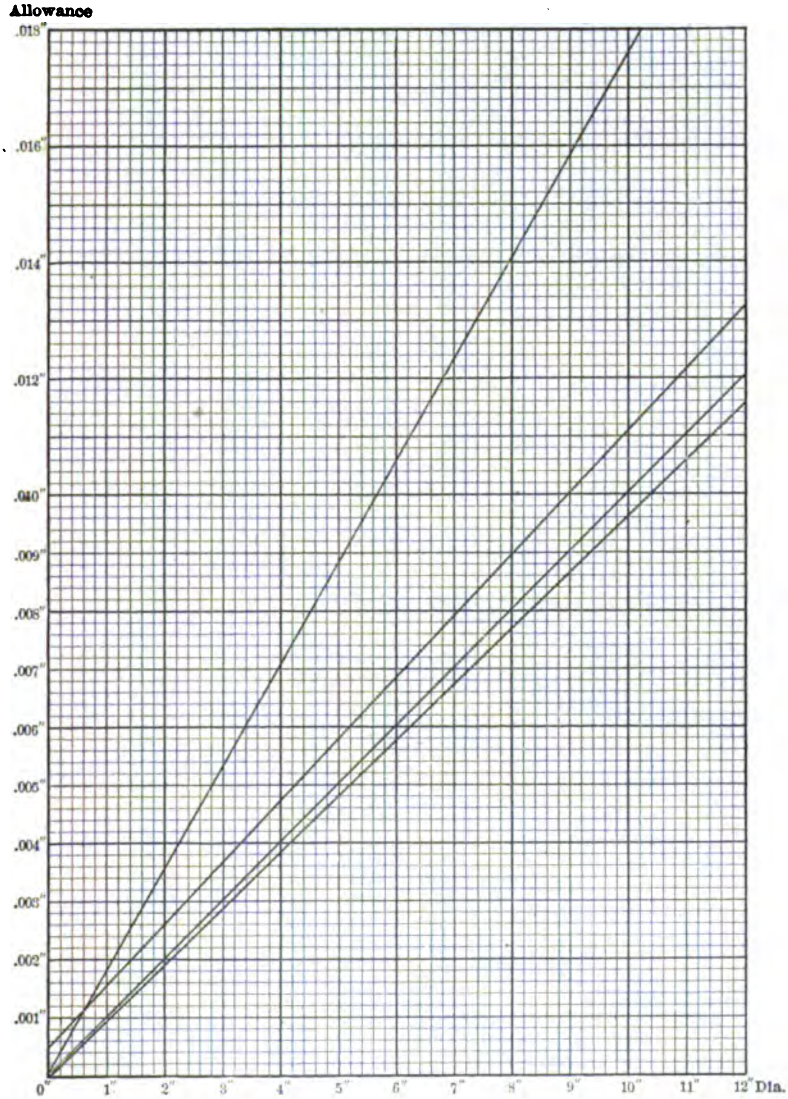
16. For those who may not know, in passing, it might be well to give a few cautionary paragraphs regarding the production of satisfactory running fits. Regarding the truth and accuracy of bored holes, practice indicates that the best results are obtained with a very light cut, a high speed and slow feed. In light chuck work there is a tendency in tightening the chuck jaws to distort the piece, and it may be necessary in some instances to partially relieve the pressure for the light finishing cut. The most satisfactory results are obtained, in fitting, where limit gauges are used; where no limit gauges are to be had, in many instances it will be found advantageous to finish the bore first, as it is easier to fit the shaft to the hole than vice versa. When a fit is made, any tool marks left on either the shaft or the bore



TYPICAL FORCING FIT PRESSURE DIAGRAM.

FIG. 238.

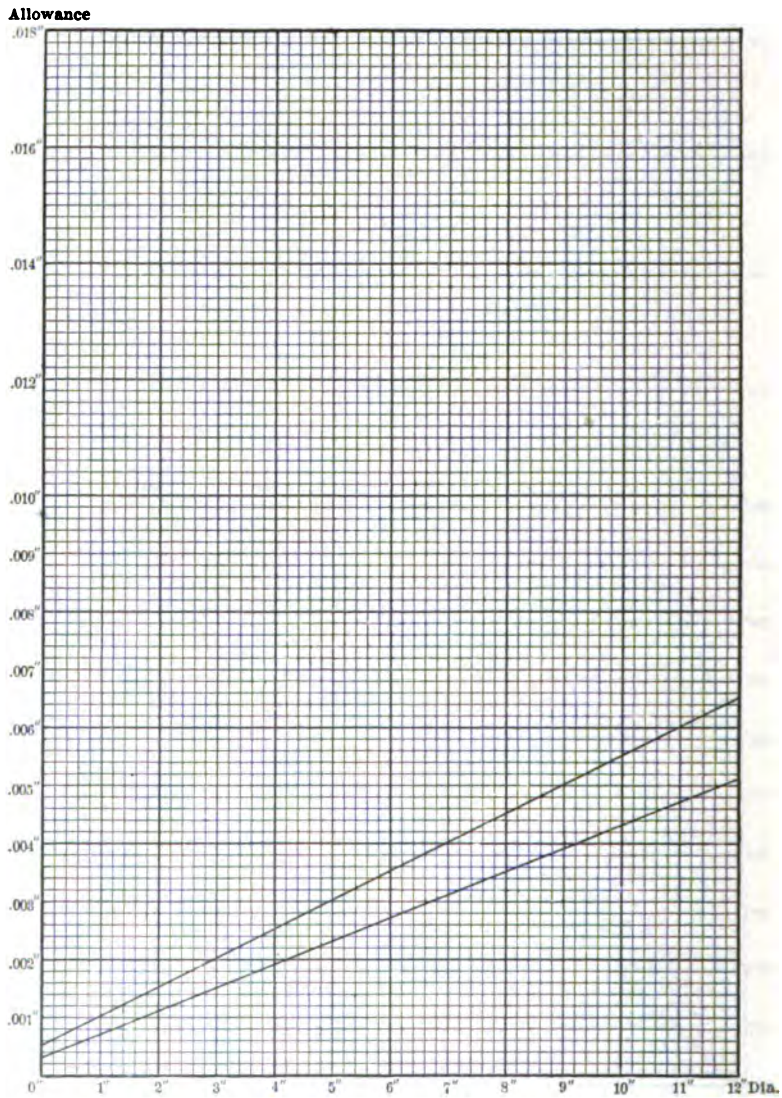
wear away rapidly and defeat the purpose of the work. Not only is their helical construction conducive to rapid wear, but it renders perfect lubrication almost impossible, as the grooves tend to lead the oil out of the bearing. It is desirable to have the surfaces in contact ground, as they then approach perfection;



TYPICAL SHRINKING FIT DIAGRAM.

FIG. 239.

where this is not feasible they should be filed and polished. On good work a very few strokes of the file will suffice to remove the tool marks; little or no filing should be attempted after their removal, as the filing of cylindrical work is at its best a negative process where truth and accuracy are to be sought.

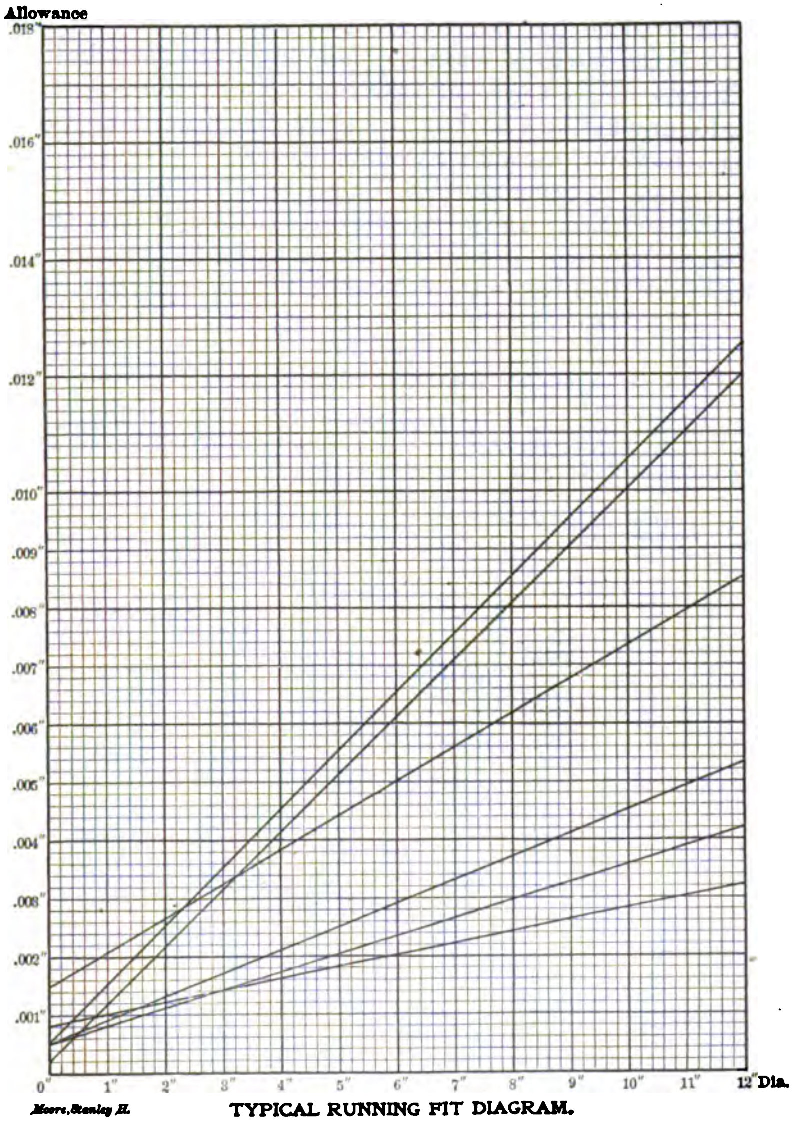


TYPICAL DRIVING FIT DIAGRAM.

FIG. 240.

Limits for Limit Gauges.

17. Limit gauges, as we are well aware, are used primarily as time savers; they avoid the waste of time in finishing parts unduly accurately, while still having them accurate enough to meet all the demands of interchangeable manufacture. The selection of the



TYPICAL RUNNING FIT DIAGRAM.

FIG. 241.

limits of variation for any given class of work requires experience and sound judgment. As it is clearly a matter of time-saving, the problem resolves itself into two phases: the accuracy and efficiency of the machine on the one hand, and the rapidity of production on the other. The largest limit of variation then that will produce the desired accuracy and efficiency in the machine, is the one to be selected. For this reason the selection of a Representative Curve of limits proves a hazardous undertaking for any but he who has to do with the production of the machine; however, the author ventures the curve plotted on the limits diagram as being suitable for machine tool, engine work and similar practice. In the manufacture of limit gauges there are reasons why one of the sets should be made one-half the allowable variation larger than the nominal size, while the other

TABLE OF TABULATED DATA RELATIVE TO FITS AND FITTING.

In order to place the results of this investigation in the most convenient form, that adequate for ready reference, the allowance values for each class of fits were calculated and tabulated under the following arrangement.

Pressure Factors.	Nominal Diameter of Fit.	Forcing Fit Allowances.	Shrinking Fit Allowances.	Driving Fit Allowances.	Running Fit Allowances.	Limits for Limit Gages.
	$\frac{1}{4}$			.0006	.00058	.00035 + or —
	$\frac{1}{2}$			.0008	.00065	.00039 "
	$\frac{3}{4}$			.0009	.00073	.00044 "
391	1	.0025	.0016	.0010	.0008	.0005 "
319	$1\frac{1}{2}$	.0035	.0021	.0013	.0010	.0006 "
240	2	.0045	.0026	.0015	.0011	.0007 "
156	3	.0065	.0037	.0020	.0014	.0009 "
115	4	.0085	.0048	.0025	.0018	.0011 "
91	5	.0105	.0058	.0030	.0021	.0012 "
75	6	.0125	.0069	.0035	.0024	.0014 "
64	7	.0145	.0079	.0040	.0027	.0016 "
55	8	.0165	.0090	.0045	.0030	.0018 "
48.5	9	.0185	.0101	.0050	.0033	.0020 "
43	10	.0205	.0111	.0055	.0036	.0022 "
39	11	.0225	.0122	.0060	.0039	.0024 "
36	12	.0245	.0133	.0065	.0043	.0026 "
30.4	14	.0285	.0154	.0075	.0049	
26.4	16	.0325	.0175	.0085	.0055	
23.3	18	.0365	.0196	.0095	.0061	
20.8	20	.0405	.0218		.0068	
18.8	22	.0445	.0239		.0074	
17.2	24	.0485	.0260		.0080	
15.1	27	.0545	.0292		.0090	
13.5	30	.0605	.0324		.0099	
	38		.040			
	44		.047			
	50		.053			
	56		.060			
	62		.066			
	66		.070			
$PF = \frac{500}{D^{1.05}}$		$\frac{A}{1000} = 2D + .5$	$\frac{A}{1000} = 1\frac{1}{16}D + .5$	$\frac{A}{1000} = \frac{1}{2}D + .5$	$\frac{A}{1000} = \frac{5}{16}D + .5$	$\frac{\frac{1}{2}L + \text{or} -}{1000} = \frac{1}{16}D + 3$

A glance at the Representative Curves of the various fits and their formulas reveals the allowances to bear the following relations to each other: 5, 8, 17, 32, starting with the curve for running fits.

set should be made just as much smaller. This, it is believed, is the practice of the best manufacturers, though in some of the data investigated such was not the case. The representative formula $\frac{L}{2} = \frac{3}{16} D + .3$ gives half the limit variation in thousandths of an inch, plus or minus as desired.

18. While the specific values obtained from the formulae, diagrams and table will prove, no doubt, of great value to many, they should be taken as a guide indicating the conditions which existed in the data which the author was able to procure. As it is impossible for one individual to secure and tabulate that amount of information from the thousands of progressive machine shops of this country, necessary to indicate the average American practice in this direction, the greatest value of this paper may be found in its discussion by those who know, and again in its indication of what may be done with similar masses of seemingly chaotic data.

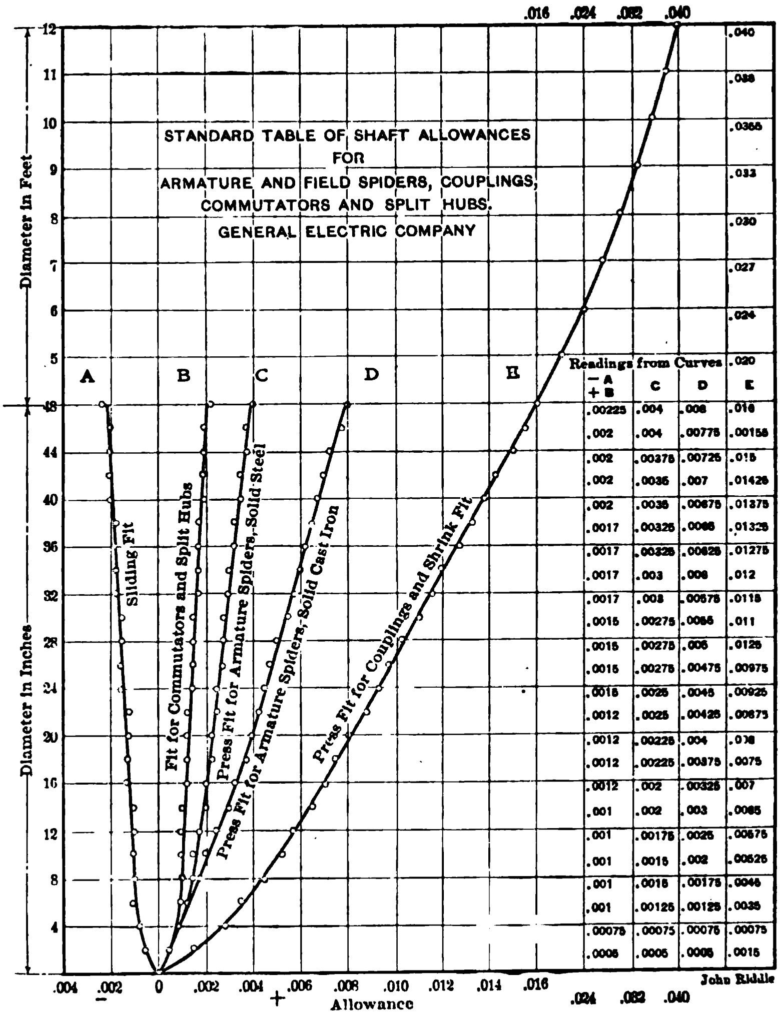
DISCUSSION.

Mr. John Riddell.—I have read the paper by Mr. Stanley H. Moore, on fits and fitting, with a great deal of interest, and am very glad to see that some effort is being made to get the matter of allowances put in some tabulated form for future reference. I am particularly interested in this subject at this time, as I have just proposed a diagram for our own use, and was just about to issue it.

In making up such tables and diagrams, it will be found a very difficult undertaking to make them to suit all conditions, as I will try to point out.

Before making any change in our present allowances I wrote to a number of engine builders for their opinion regarding the change, and received answers from about 40 of them, and the answers furnished very interesting reading matter; some suggested that the present allowance was all right, others said the proposed allowance would be about right, while still others said it was not enough.

My reasons for changing were, first, to have a gradually increasing allowance, and not in steps by 3 or 4 inches, because I contend that if an allowance is right for 10 inches the same allowance would not be right for 14 or 15 inches. Second, our old allowance is 50 per cent. smaller than the proposed allow-



Readings from Curves −A +B	C	D	E
.00225	.004	.008	.016
.002	.004	.00775	.0155
.002	.00375	.00725	.015
.002	.0035	.007	.01425
.002	.0035	.00675	.01375
.0017	.00325	.0065	.01325
.0017	.00325	.00625	.01275
.0017	.003	.006	.012
.0017	.003	.00575	.0115
.0015	.00275	.0055	.011
.0015	.00275	.005	.0125
.0015	.00275	.00475	.00975
.0015	.0025	.0045	.00925
.0012	.0025	.00425	.00875
.0012	.00225	.004	.008
.0012	.00225	.00375	.0075
.0012	.002	.00325	.007
.001	.002	.003	.0065
.001	.00175	.0025	.00575
.001	.0015	.002	.00525
.001	.0015	.00175	.0045
.001	.00125	.00125	.0035
.00075	.00075	.00075	.00075
.0005	.0005	.0005	.0015

Fig. 242.

ance, and gave no leeway to the shaft turner. There are many things to be taken into consideration in laying out these tables and diagrams: first, the relation of length of bore to diameter; in our case the length of hubs of armature spiders are sometimes several times the diameter, but the actual bearing surface is about equal in length to the diameter, on account of recesses in the hub. Second, the outside diameter of hub should be taken into consideration. My diagram is laid out on the basis of the hub being twice the diameter of the shaft. Third, the nature of the materials should be considered. Fourth, how and where the parts are to be assembled; if they are to be assembled where a suitable hydrostatic press is available, more allowance can be made than if the parts are to be put together by the use of bolts and straps.

My diagram is based on actual experience extending over a number of years, and the one we have at present in use is eminently satisfactory.

In laying out the diagram we took the largest bore we had made and different smaller ones down to 2 or 3 inches, and plotted the curve to suit.

In my diagram I differ very widely from Mr. Moore in all of his tables, and also in some of his general deductions.

By comparing some of his tables with our experience we have :

FORCING FIT.

	MOORE.	RIDDELL.
6 inches	.0125	.00125
12 "	.0245	.00425
24 "	.0485	.0045
30 "	.0605	.0055
37 "	.....	.0065

SHRINK FIT.

	MOORE.	RIDDELL.
6 inches..............	.0069	.0035
12 "	.0133	.0057
24 "	.0260	.00925
30 "	.0324	.011
37 "	.....	.01325
12 feet...	.....	.040 inch.

It will be noticed by the above that Mr. Moore allows about ten times more for pressure fits than in my proposed table.

It will also be noticed that Mr. Moore allows less for shrinkage than for pressing, while my table gives double the amount.

I would like to call attention to another statement made on paragraph 12 of Mr. Moore's paper, in which he says more skill and experience are required for shrinking than for force fits. I have seen a great many fits of both kinds made and never heard this statement made before. If a piece is being bored for shrinkage, say about 48 inches diameter, we would allow .016 inch, but if the same piece was to be bored for forcing fit we would only allow .008 inch. Two or three thousandths would make very little difference on the shrinkage fit, as we would be sure to have a tight fit if there was such a variation either way ; but in the case of forcing, if .003 inch were taken from .006 inch, the pressure would be insufficient, and if the same amount was added, the pressure would be entirely too high.

One of the reasons for making my table was to have something for the guidance of our designers and draughtsmen.

There are five curves shown, and are as follows (Fig. 242):

The left-hand one on the minus side of *O* line shows allowances for sliding fit; I mean by this such fits as are not loose or free like a running fit, but one that will just slide without any perceptible play.

The next curve is on the right or plus side of the *O* line, and shows exactly the same allowances for tight fits, for parts with light hubs, such as commutator shells, etc.

The third curve gives somewhat greater allowances, and is used for steel hubs.

The fourth is for our regular armature spiders of solid cast-iron hubs.

The fifth shows the amount we have found to be correct for shrinkage fits, and for such heavy articles as couplings.

Our bearings, or running fits, are not given, as it was not thought advisable to put too much on one sheet.

Without assigning names to the individual replies, it may be of interest for me to give the following list of builders and manufacturers to whom my inquiries were sent, and the tenor of their replies. The list includes:

THE HOOVEN, OWENS, RENTSCHLER COMPANY.
THE LANE & BODLEY CO.
THE WESTINGHOUSE MACHINE COMPANY.
THE WEBSTER CAMP & LANE CO.
ROBERT WETHERILL & CO.
THE C. & G. COOPER COMPANY.
PHŒNIX IRON WORKS COMPANY.
McINTOSH, SEYMOUR & CO.
SKINNER ENGINE COMPANY.
AMERICAN ENGINE COMPANY.
FITCHBURG STEAM ENGINE COMPANY.
PROVIDENCE ENGINEERING WORKS.

THE WILLIAM TOD COMPANY.
QUINCY ENGINE WORKS.
ERIE CITY IRON WORKS.
NICHOLS & LANGWORTHY MACHINE COMPANY.
WILLIAM A. HARRIS STEAM ENGINE COMPANY.
AMERICAN MACHINE & ORDNANCE CO.
BATES MACHINE COMPANY.
PROVIDENCE ENGINEERING WORKS.
BUFFALO FORGE COMPANY.
A. L. IDE & SONS.
WATERTOWN ENGINE COMPANY.
BROWN CORLISS ENGINE COMPANY.
S. MORGAN SMITH COMPANY.
BUCKEYE ENGINE COMPANY.
PAYNE ENGINE COMPANY.
PENNSYLVANIA IRON WORKS COMPANY.
THE FILER & STOWELL CO.
HARRISBURG FOUNDRY & MACHINE WORKS.
ATLAS ENGINE WORKS.
THE WATTS-CAMPBELL COMPANY.
THE BALL & WOOD CO.

"We have gone over the matter carefully, and we should think that the new allowances would be all right for armatures, and trust you will continue to name the allowances we are to make in turning our shafts. We, of course, allow much more than the above for our crank and fly-wheel pressure fits, but should think that for your armatures these would be just about the right allowances."

"We have felt that the electric companies' allowances have in many cases been less than the limit of error, especially on the larger sized shafts from 18 inches up, as it appears very difficult to get any two men to caliper alike on these large diameters, even with very carefully designed calipers."

"We have always thought that your present allowance is very small, and compared with our own practice, your proposed allowance is still what we would consider extremely moderate."

"In our practice for cranks, crank-pins, fly-wheel centres, etc., we have always allowed considerably greater difference than the allowance proposed in your letter of November 18, 1902."

"We notice that your proposed allowances are a decided increase over your present practice, and we believe is a step in the right direction. Of course, in the case of steel castings, we only make about one-half the allowance provided for in the accompanying blue print."

"The proposed allowance that you contemplate making, we think, is a step in the right direction. The units we have handled have not fallen below shaft of 9 inches diameter. We always considered your present allowance a little small, and as a matter of fact have been keeping our shaft sizes nearer to the allowance you now propose to insure good tight fit of the work."

"Have compared your proposed allowance for press fits to what we have been accustomed to putting on our fly-wheel centres, and find that they about agree, and that it gives us a press fit of 8,000 to 10,000 pounds to the inch diameter. When it comes to pressing steel cranks, which we frequently have to put on to our shafts, we find that we have to reduce the differences to about half of what is given for cast-iron. In other words, if any of the armatures were steel, we would think your allowances ought to be cut in two to get the same pressure that you are getting with the larger allowance that the armatures are cast-iron."

"Would say that we enclose a table that we have compiled from our own practice, and an allowance of .002 inches per inch of diameter which Professor Sweet of The Straight Line Engine Company uses. According to Professor Sweet's practice, the allowance will be very heavy compared with your proposed system of allowances. Our own practice has answered very well for such things as cast-iron crank-discs, but even ours is on much smaller allowance than that advocated by Professor Sweet. We think your present system of sizes for forced fits is rather under what it should be, but it is very hard to get a rule that will apply to cast-iron discs and cast-steel discs."

"We have your circular letter of the 18th in regard to press fits. We never figure on being able to find apparatus for pressing on hubs of wheels or cranks where the engine is erected, and this is generally done in the shop in any case, so our advice is of no value as to whether there will be trouble on account of heavy pressures required with your proposed allowance. We would say that for wheel hubs, where they are solid, we make an allowance which is .0001 D + .005 inches, where D is the diameter. This allowance, you will note, is intended to apply only to fits over 12 inches diameter, and you will note is a greater allowance than your proposed standard, and we have no trouble about putting these on in the shop; but of course our crank-pin fits call for a much greater allowance, and we are therefore used to heavy pressures. We do have an allowance for the boring of split wheels of $.0001\ D + .002$ inches, which is more nearly like your present allowance, but of course we have both shaft and wheel in the shop, and fit one to the other, and the wheel hub has to be stretched by the bolts at the split so as to bring it together, which limits the amount of allowance possible. Our practice is to turn the shaft nominal, or even diameter, and bore the hub the proper allowance smaller. We note the Westinghouse Electric Company pursue the same method; also they send us a gauge the exact size the shaft should be instead of asking us to make the allowance. We think this method is preferable to yours."

"We have your circular letter of the 18th regarding the matter of changing the amount of pressure-fit allowance which we make on shafts to fit your armatures.

"We would state that we have so little forcing of armatures on shafts to do that we are not very well able to judge in a matter of this kind. We generally finish the shaft to the instructions we receive from the dynamo builder. In most cases where we have direct-connected with your dynamos, we have sent the shafts to your works, and of course you would be the best judges of the amount of pressure-fit allowance. Whenever we have had to place the armatures on the shafts we have never had much of any trouble, because we have always sent experienced men.

"We have never had any complaint that our shafts were other than exactly to gauge, so that we presume either way our shafts would be made satisfactorily."

"We think from our own experience that your present allowance is all that can actually be used with the appliances available in putting the armatures on the shafts, and in fact, in most cases, we find that the shafts have to be draw-filed considerably before the armature can be forced into position with the single stud in the end of the shaft."

"We have yours of the 18th, and in reply would say that we are well satisfied at present with the allowance you make, and have never had any complaint as to their being too tight or too loose, from any one of the many shafts we have sent out to fit your armatures. If the shafts are made correctly to your gauges with the allowance you name, it seems to us there is sufficient pressure required to fit the usual condition of things where they are put together."

"I would say that your new schedule for proposed allowances is in the neighborhood of $\frac{1}{8}$ of what we are allowing for crank-discs, hubs of fly-wheels, crank-pins, etc., coming within scope of the various sizes mentioned. Of course, the stresses which these pieces have to stand is probably greater than the stresses imposed upon your armatures, and the nature of the pieces also allows subjecting them to a greater force fit. We would say in general that the proposed allowances, or even more, would be advantageous if the structure of your armatures would allow their being pressed on with this increased allowance."

"We beg to state that we see no objections to the proposed change in allowances for generator shafts."

"Replying to your favor of the 18th inst., in regard to the allowance of press fits, we find from experience that the amount depends upon the material, class of work, hub, and mild steel shaft, with depth of hub equal to the diameter of shaft. The hub bored smooth and round, and the shaft turned true and smooth, clear of tool-marks, we consider the present allowance about right; but for press-fit allowance for the ordinary boring and turning with coarse feeds and tool-marks left in, the proposed allowance is about right."

"Your proposed allowance table agrees almost identically with our own practice throughout our shops for the different size fits that we make, and meets very heartily with our approval."

"We do not know to what the pressure would be increased by the proposed allowances; we should think much would depend upon the facilities for forcing, which we should suppose would not exceed 20 tons in most cases. In our work we run from 20 to 60 tons according to circumstances. We should not expect trouble from an armature fit of 20 tons if it was properly made on shafts up to 6 inches or 7 inches diameter."

"Will say that we believe you are moving in the right direction. Our practice for cast-iron hub fits, on open hearth forged steel shafts, is to allow about double the amount named in your table of proposed allowances on shafts from 6 inches up."

"Would say the proposed change making greater allowance for generator fits is approved by us. It reduces the chances of getting a loose fit for the generator, without increasing the pressure required to put it on the shaft unreasonably."

"We agree with you it would be a little better to increase the allowance over what you have been using; in fact, we have always made a little greater allowance than your gauges call for when making an armature fit."

"We note the distinction you make between the split and solid hubs. Would say in this connection, we formerly made a similar distinction between split fly-wheels and those with solid hubs, but finally came to the conclusion that there was no necessity for making this distinction, as split hubs were readily clamped onto the shafts even when the full force-fit allowance was made. If this information is of any value to you, we are pleased to have furnished it."

"Your circular letter of the 18th inst., in regard to allowance which you propose for force fits on the armature bores, has been referred to the factory, and receives their approval."

"We believe that your present allowances are correct. However, so far as we are concerned, there are no objections to increasing these allowances as proposed. Where the armature and shaft are assembled in the shops, it seems to us that the only question involved in the change of the allowances is that of the strength of the armature hubs to stand the increased pressure, and of course this is a point which you will provide for."

"For one reason we are rather inclined to favor the small allowance—namely, the danger that a shaft may be sprung in the attempt to force an armature shaft on over a large allowance. Of course, where the armature shaft is separate and coupled to the engine shaft, or where the purchase is against a bolt in the end of the shaft, there is practically little danger; but we have occasionally suffered from sprung shafts in cases where the erecting engineer has attempted to get a purchase on some part of the crank itself. From an engine builder's point of view, therefore, there is some danger in too large an allowance than in too small a one. On the other hand, we appreciate the fact that a loose fit might be a much more serious matter to you than to us, and we are quite willing to follow any standard that you may decide to make."

"It is a pretty difficult thing for us to give you any definite information, as our own allowances are so entirely different from those you propose. For instance, on a crank of 15 to 18 inches diameter we would allow from .017 to .018 pressure fits, where you allow only .0055. Of course we appreciate the fact that it is necessary for you to reduce the forcing fits on account of lack of conveniences in erecting."

"Would state that the proposed allowances are just about the way we make our fits at the present time, and your proposed modifications, therefore, meet with our approval."

"From our experience the increase which you suggest would not be necessary, if you actually get what you call for, as the revolving piece of your generators is of such construction that the allowance which you have been using is quite sufficient to get all the pressure necessary under the conditions—that is, in our judgment. If you had but one straight, comparatively short fit, the allowance would not be nearly enough; but when it is so long, and two or more fits to be made, it would, as we said before, seem to us that yonr former allowance was sufficient."

"We believe that the proposed allowance mentioned in your circular would be safer than the present allowance."

"We entirely agree with you that your present allowance is not at all sufficient, and as a matter of fact, we have invariably made a rule at our works to leave our shafts at least .001 inch larger than the requirements suggested by you.

"As we are very seldom interested in fits less than 12 inches, we take the liberty of suggesting that all the allowances proposed from 12 to 18 inches are, in our opinion, at least .003 inch too small still; in other words, in fits from 12 to 15 inches we would allow .008 inch, and 15 to 18 inches we would allow .0085 inch, and above 18 inches we would allow .009 inch.

"In fact, we make greater allowances than this on our fly-wheel discs, which are forced on under very similar strain, and we may say that the allowances made by the Westinghouse company, on similar fits, are generally slightly greater than the additions we have suggested to your proposed allowances."

"We think the proposed allowance will be more satisfactory. Even with the increase, the allowance is away below the ordinary practice on general work. Of course your reason for keeping allowance so small on account of poor facilities in many power stations is well founded, but we think there will be very little trouble on that score on account of the change. We find that our shop has been in the habit of leaving fits for dynamos on engine shafts about .001 inch larger than your gauges required."

"We beg to say that we cannot see that the proposed change will be altogether out of place, although we feel that it would increase very much the difficulty of erection on the road.

"We frequently find that with the allowances that you make at present that the shafts have to be, in many cases, draw-filed before it is possible to get the armature on."

"In our experience the present allowances seem quite sufficient. If, however, you have had considerable trouble of late, may it not be that you do not get diameter of shaft giving the allowance now called for? If it is necessary to specify .006 inch in order to get actually .004 inch, there is possibly no harm in doing so with those people whom you find skimping their dimensions. It certainly seems to us that your present allowance, if lived up to, should be quite satisfactory."

"Our allowances are on an average 40 per cent. greater than your proposed allowance. This is for wheel hubs, cranks and crank-pins. The length of the hub of any piece of cast-iron is a great factor in determining the allowance. A hard casting, in our experience, needs but one-half that of a soft one. We allow for a hard casting 18 inches bore and 14 inches length of hub, .007 inch, and for a soft casting .014 to obtain about 75 tons pressure."

"So far as our experience extends, we have found the present allowances between armature bore and shaft diameter ample for pressing fit, and do not know a case where the armature has worked loose on one of our shafts. To increase materially this pressure for shafts of given sizes would, in our opinion, increase the chances of damage to the shafts, and we feel that this risk is at present great enough."

Mr. John Calder.—I think the author of the paper has received from various manufacturers, using very different kinds of machinery, a great deal of data. It so happens that my work, being connected with very exact fits and duplicate parts, has been such as to enable me to construct a table for my own work (see table appended), and I have compared it very carefully with the one given at the end of this paper; it may be of interest to state one or two of the results.

TABLE OF PRESS, DRIVE, AND HAND FITS.

Prepared by Mr. John Calder.

Diameters		1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	7 in.	8 in.	9 in.	10 in.	Formula:
Press Fit	Shaft	+ .001	+ .002	+ .003	+ .004	+ .005	+ .006	+ .007	+ .008	+ .009	+ .010	+ (.001 d + .000)
		+ .002	+ .003	+ .004	+ .005	+ .006	+ .007	+ .008	+ .009	+ .010	+ .011	+ (.001 d + .001)
Drive Fit	Shaft	+ .0005	+ .001	+ .0015	+ .002	+ .0025	+ .003	+ .0035	+ .004	+ .0045	+ .005	+ (.0005 d + .000)
		+ .0015	+ .002	+ .0025	+ .003	+ .0035	+ .004	+ .0045	+ .005	+ .0055	+ .006	+ (.0005 d + .001)
Hand Fit	Shaft	− .001	− .001	− .001	− .002	− .002	− .002	− .003	− .003	− .003	− .003	....
		− .002	− .002	− .002	− .003	− .003	− .003	− .004	− .004	− .004	− .004	....
All Fits	Hole	+ .000	+ .000	+ .000	+ .000	+ .000	+ .000	+ .000	+ .000	+ .000	+ .000	....
		− .002	− .002	− .002	− .003	− .003	− .003	− .004	− .004	− .004	− .004	....

TABLE 1—LIMITS TO DIAMETERS OF PARALLEL SHAFTS AND BUSHINGS (SHAFTS CHANGING).

Diameters		1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	7 in.	8 in.	9 in.	10 in.	Formula:
Close Fit	Shaft	− .003	− .004	− .005	− .006	− .007	− .008	− .009	− .010	− .011	− .012	− (.001 d + .002)
		− .005	− .006	− .007	− .008	− .009	− .010	− .011	− .012	− .013	− .014	− (.001 d + .004)
Free Fit	Shaft	− .008	− .009	− .010	− .011	− .012	− .013	− .014	− .015	− .016	− .017	− (.001 d + .007)
		− .011	− .012	− .013	− .014	− .015	− .016	− .017	− .018	− .019	− .020	− (.001 d + .010)
Loose Fit	Shaft	− .023	− .026	− .029	− .032	− .035	− .038	− .041	− .044	− .047	− .050	− (.003 d + .020)
		− .028	− .031	− .034	− .037	− .040	− .043	− .044	− .049	− .052	− .055	− (.003 d + .025)
All Fits	Hole	+ .000	+ .000	+ .000	+ .000	+ .000	+ .000	+ .000	+ .000	+ .000	+ .000	....
		− .002	− .002	− .003	− .002	− .003	− .003	− .003	− .004	− .004	− .004	....

TABLE 2—LIMITS TO DIAMETERS OF PARALLEL JOURNALS AND BEARINGS (JOURNALS CHANGING).

Diameters		1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	7 in.	8 in.	9 in.	10 in.	Formula:
Press Fit	Hole	− 5 P	− 6 P	− 7 P	− 8 P	− 9 P	− 10 P	− 11 P	− 12 P	− 13 P	− 14 P	− (Pd + 4 P)
		− 6 P	− 7 P	− 8 P	− 9 P	− 10 P	− 11 P	− 12 P	− 13 P	− 14 P	− 15 P	− (Pd + 5 P)
Drive Fit	Hole	− ½ P	− 1 P	− 1½ P	− 2 P	− 2½ P	− 3 P	− 3½ P	− 4 P	− 4½ P	− 5 P	− (½ Pd + 0)
		− 1 P	− 2 P	− 2½ P	− 3 P	− 3½ P	− 4 P	− 4½ P	− 5 P	− 5½ P	− 6 P	− (½ Pd + P)
Hand Fit	Hole	+ 0	+ 0	+ 0	+ 0	+ 0	+ 0	+ 0	+ 0	+ 0	+ 0	+ 0
		− 1 P	− 1 P	− 1 P	− 1 P	− 1 P	− 1 P	− 1 P	− 1 P	− 1 P	− 1 P	− P

TABLE 3—LIMITS TO DIAMETERS OF TAPER SHAFTS AND BUSHINGS (HOLES CHANGING).

Taking the driving fits, I find that Mr. Moore's formula

$$\left(\frac{A}{1,000} = \frac{1}{2} D + .5\right)$$

is equivalent to my

$$\left(\frac{D}{1,000} + \frac{5}{10,000}.\right)$$

The formulæ are identical in this respect, and I can confirm the value of the figures regarding the "driving fits." In the "forcing" or "press fits," however, the allowance given by Mr. Moore for excess diameter of shaft is too great. His formula reduced to the form we use would be $\frac{2}{1000} D + \frac{5}{10000}$, whereas we use only $\frac{1}{1000} D + \frac{5}{1000}$ and find it ample, the pressure being from 15 to 22 tons to press up. Anything greater would burst the hubs of ordinary wheels. Mr. Moore's "shrinking fit" allowance, in fact, is identical with our "press" fit limits. In the "running fits," the formula given by Mr. Moore gives a four times finer fit than is ordinarily used by us—say, on small trucks and industrial railway work, it seems to me that such fine running fits as are given by the author are quite impracticable. The "driving fits" are identical with our practice, and give a good result; the "press fit" being only half the allowance we give, and the "running fit" being far too fine for ordinary work.

Mr. McGeorge.—I would like to ask some questions perhaps not directly connected with fits. First, is it advisable to mark upon the drawings the different kinds of fits, or should this be left entirely to the shop foreman? I have been seriously considering some method by which we could instruct the men in the shop where to leave these different kinds of fits. One particular instance that I have in mind is this: Some large rolling mill tables were made with cast-iron sides and with square brasses let into them (the great trouble with nearly all this class of machinery is making too fine fits), and $\frac{1}{100}$ of an inch was left between the size of the brasses and the size of the openings in the cast-iron. That is, the opening was made of the exact size, and the brass was shaped $\frac{1}{100}$ of an inch smaller so that it would go in freely. I know from my own personal experience that the first time they were taken out they would be tight and have to be pulled out. The inspector objected very strongly to what he called slipshod fitting, but I think any one who has had very much experience will agree that it was not at all slipshod fitting. Now, the question I would like to ask about that is:

Should that have been left to the shop foreman, or should it have been indicated upon the drawing? You get upon a shaft a great number of different kinds of fits. You get a wheel pressed on—a press fit; you get a journal—a running fit; you get a loose pulley; you get a wheel that you want to take off occasionally, which is a sliding fit. Now, how should all those things be indicated; should that be done in the shop, or indicated on the various parts that go on the shaft?

Mr. Fred J. Miller.—In respect to the question asked by Mr. McGeorge, as to whether the character of the fits in a given case should be stated upon the drawing or should be left to the shop foreman, I would say that that is one of the questions which is being discussed a great deal. I have given some attention to it, and my conclusion is that you cannot lay down a rule which will always be right in every case, because so much depends upon the character of the work. If there is any one in the shop who knows all about the kind of work that is to be done—if, for instance, the shop foreman is the only man in the works who knows what kind of fits should be made on a machine, then he is the one to decide that question; and if it is desirable to state it on the drawings, then the draughtsman should consult the shop foreman before he puts the information on the drawings. In many cases, of course, it is not important that the kind of fits made in a given case should be a matter of record; if it is not important then it is left to the foreman, and he makes the fits which he thinks are proper. In other cases, however, where machines are being made over and over again, or, regularly manufactured, it is important to know in each case without having to consult the foreman, and in such cases I believe the record should be made on the drawing; but only after consultation with some one who knows what sort of fits should be made.

As to whether variations in size for fitting should be made on the shaft or in the parts fitted to the shaft, I think that practice seems to have settled that those variations should always be made on the shaft, simply because we have the tools made for producing the holes; they are usually in the form of reamers, which determine the size of the holes to be made, and which cannot be altered very well. The usual best practice is to maintain the holes as near the standard as the character of the work will permit, and then to make on the shaft the variations for the different fits required, the shaft being always finished by grinding or cutting tools, which can be readily adjusted without the alteration of any tool that is intended to be a fixed standard.

Mr. A. E. Johnson.—The last speaker mentioned the desirability of maintaining the female as the standard, and reducing the male for clearance. While this seems the only practical way to handle a standard, yet occasionally a shaft must maintain a size continuously through its bearings, and perhaps several other parts. We have sometimes in this case reduced the shaft uniformly to give the minimum clearance desired, and enlarged the holes in the other parts to give the clearance desired in them.

We once heard it stated that the Baldwin Locomotive Works could send out any part for a machine twenty years old and have it fit. When we undertake any such standardization in manufacture, it would seem necessary to first decide what "tolerances" or variations, plus or minus, in the nominal dimensions can be allowed, so that they, when combined with the nominal clearances for any given size, will give variations, or maximum and minimum clearances within reason.

We submit a study diagram and table for comparison with the free fits given by Mr. Moore. From this diagram and all others, we have seen it would seem impractical to use straight lines, because of the difficulty of combining the tolerances on the female and clearance lines, and not have them converge or give a less minimum clearance on the larger sizes—*e.g.*, the 4-inch as well as the 20-inch size has in this case .0026-inch minimum clearance. It will be noted that our "tolerance" (see seventh column on p. 1172 of Mr. Moore's paper) is for 1-inch size .007 inch, 8-inch size .0014 inch, and 20-inch size .0026 inch; surely much work could be manufactured more cheaply with a tolerance twice this, and again some would require half of this. For nominal clearances for ordinary and journal fits (see sixth column in Mr. Moore's table) we allowed for 1-inch size .0079 inch, 8-inch size .0107 inch, and 20-inch size .0155 inch, and for minimum practical free fits, for 1-inch size .004 inch, 8-inch size .0054 inch, and for 20-inch size .0078 inch. When we come to assemble we have for 8-inch size in ordinary fits a variation of from .0079 inch to .0135 inch in the amount of clearance, and in the 1-inch size a variation of from .0065 inch to .0093 inch. In the minimum free fits we find in the 18-inch size a variation of from .0026 inch to .0122 inch. In laying out these lines it was attempted to so place them that the "tolerances" and clear-

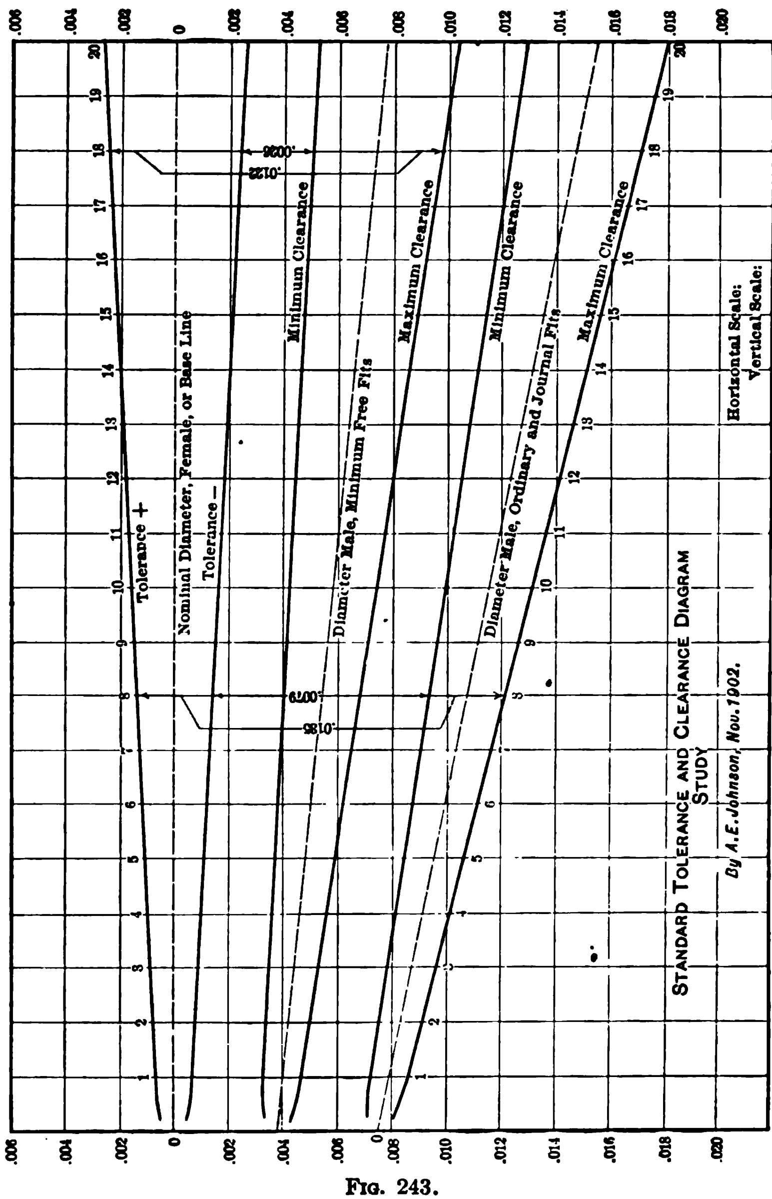


FIG. 243.

ances could be either halved or doubled, enabling the constructor to the more readily meet the requirements of different cases. It goes without saying that the most practical constructor in a manufacturing establishment is the man to be in charge of the designers in the drawing-room, and also that the diagrams and tables will secure uniformity in work and data upon which to make further modifications. Any attempt to design without them leads not only to variations in fits on each new machine designed, but loss of time guessing what we will allow for this and that fit.

We hope to submit a more workable diagram and table in the future.

STANDARD CLEARANCE AND TOLERANCE TABLE.

FEMALE.			MALE.									
Sizes.		Diameter and Tolerance.	Ordinary and Journal Fits.					Minimum Free Fits.				
			Clearances.	Sizes.		Clearance.		Clearances.	Sizes.		Clearance.	
Max.	Min.			Max.	Min.	Max.	Min.		Max.	Min.	Max.	Min.
......	......	± .0003	....	......	......	......	......	....	......	......	......	......
......	......	± .0004	....	......	......	......	......	....	......	......	......	......
.2505	.2495	.25 ± .0005	.0076	.2429	.2419	.0086	.0066	.0038	.2467	.2457	.0048	.0028
.3755	.3745	.375	.0076	.3679	.3669	.0086	.0066	.0038	.3717	.3707	.0048	.0028
.5006	.4994	.5 ± .0006	.0077	.4929	.4917	.0089	.0065	.0039	.4967	.4955	.0051	.0027
.6256	.6244	.625	.0077	.6179	.6167	.0089	.0065	.0039	.6217	.6205	.0051	.0027
.7506	.7494	.75	.0078	.7428	.7416	.0090	.0068	.0039	.7467	.7455	.0051	.0027
.8756	.8744	.875	.0078	.8678	.8666	.0090	.0068	.0039	.8617	.8605	.0051	.0027
1.0007	.9993	1. ± .0007	.0079	.9928	.9914	.0093	.0065	.0040	.9967	.9953	.0054	.0026
1.1257	1.1243	1.125	.0079	1.1178	1.1164	.0093	.0065	.0040	1.1217	1.1203	.0054	.0026
1.2507	1.2493	1.25	.0080	1.2427	1.2413	.0094	.0066	.0040	1.2467	1.2453	.0054	.0026
1.3757	1.3743	1.375	.0080	1.3677	1.3663	.0094	.0063	.0040	1.3717	1.3703	.0054	.0026
1.5007	1.4993	1.5 ± .0007	.0081	1.4926	1.4912	.0095	.0067	.0041	1.4966	1.4952	.0055	.0027
1.6257	1.6243	1.625	.0081	1.6176	1.6162	.0095	.0067	.0041	1.6216	1.6202	.0055	.0027
1.7507	1.7493	1.75	.0082	1.7425	1.7411	.0096	.0068	.0041	1.7466	1.7452	.0055	.0027
1.8757	1.8743	1.875	.0082	1.8675	1.8661	.0096	.0068	.0041	1.8716	1.8702	.0055	.0027
2.0008	1.9992	2. ± .0008	.0083	1.9925	1.9909	.0099	.0067	.0042	1.9966	1.9950	.0058	.0026
2.2508	2.2492	2.25	.0084	2.2424	2.2408	.0100	.0068	.0042	2.2466	2.2450	.0058	.0026
2.5008	2.4992	2.5	.0085	2.4923	2.4907	.0101	.0069	.0043	2.4965	2.4949	.0059	.0027
2.7508	2.7492	2.75	.0086	2.7422	2.7406	.0102	.0070	.0043	2.7465	2.7449	.0059	.0077
3.0009	2.9991	3. ± .0009	.0087	2.9922	2.9904	.0105	.0069	.0044	2.9965	2.9947	.0062	.0026
3.2509	3.2491	3.25	.0088	3.2421	3.2403	.0106	.0070	.0044	3.2465	3.2447	.0062	.0026
3.5009	3.4991	3.5	.0089	3.4920	3.4902	.0107	.0071	.0045	3.4964	3.4946	.0063	.0027
3.7509	3.7491	3.75	.0090	3.7419	3.7401	.0108	.0072	.0045	3.7464	3.7446	.0063	.0027
4.0010	3.9990	4. ± .0010	.0091	3.9919	3.9899	.0111	.0071	.0046	3.9964	3.9944	.0066	.0026
4.2510	4.2490	4.25	.0092	4.2418	4.2398	.0112	.0072	.0046	4.2464	4.2444	.0066	.0026
4.5010	4.4990	4.5	.0093	4.4917	4.4897	.0113	.0073	.0047	4.4963	4.4943	.0067	.0027
4.7510	4.7490	4.75	.0094	4.7416	4.7396	.0114	.0074	.0047	4.7463	4.7443	.0067	.0027
5.0011	4.9989	5. ± .0011	.0095	4.9916	4.9894	.0117	.0073	.0048	4.9963	4.9941	.0070	.0026
5.2511	5.2489	5.25	.0096	5.2415	5.2393	.0118	.0074	.0048	5.2463	5.2441	.0070	.0026
5.5011	5.4989	5.5	.0097	5.4914	5.4892	.0119	.0075	.0049	5.4962	5.4940	.0071	.0027
5.7511	5.7489	5.75	.0098	5.7413	5.7391	.0120	.0076	.0049	5.7462	5.7440	.0071	.0027
6.0012	5.9988	6. ± .0012	.0099	5.9913	5.9889	.0123	.0075	.0050	5.9962	5.9938	.0074	.0026
6.2512	6.2488	6.25	.0100	6.2412	6.2388	.0124	.0076	.0050	6.2462	6.2438	.0074	.0026
6.5012	6.4988	6.5	.0101	6.4911	6.4887	.0125	.0077	.0051	6.4961	6.4937	.0075	.0027
6.7512	6.7488	6.75	.0102	6.7410	6.7386	.0126	.0078	.0051	6.7461	6.7437	.0075	.0027
7.0013	6.9987	7. ± .0013	.0103	6.9910	6.9884	.0129	.0077	.0052	6.9961	6.9935	.0078	.0026
7.0013	7.2487	7.25	.0104	7.2409	7.2383	.0130	.0078	.0052	7.2461	7.2435	.0078	.0026
7.5013	7.4987	7.5	.0105	7.4908	7.4882	.0131	.0079	.0053	7.4960	7.4934	.0079	.0027
7.7513	7.7487	7.75	.0106	7.7407	7.7381	.0132	.0080	.0053	7.7460	7.7434	.0079	.0027
8,0014	7.9986	8. ± .0014	.0107	7.9907	7.9879	.0135	.0079	.0054	7.9960	7.9932	.0082	.0026

For very close work the Tolerance may be halved.

Mr. John Calder.—About a year ago the question came up where I am engaged as to just what are the proper "fits," how they are to be recorded, and so on. The foreman of the shops

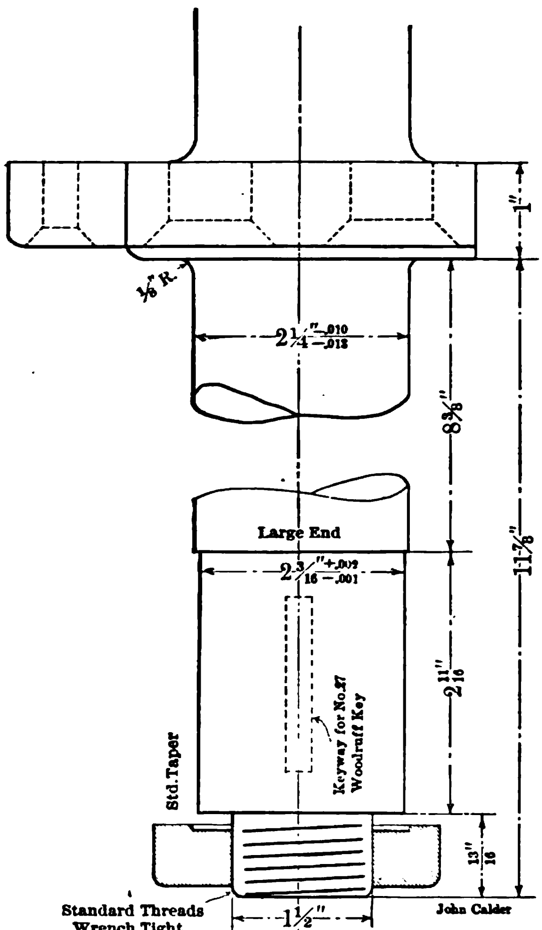


FIG. 244.

did not know, the head draughtsman did not know, nor did any of the draughtsmen in the office know—in fact, nobody knew. We asked the men, but could find out nothing. After some consideration and investigation among the outside erectors and users of machinery, we drew up tables, had them printed, and then appointed one of the draughtsmen in the draughting-room to attend to them. These tables were edited from time to time as experience directed, and after he was thoroughly conversant with all the facts, we instituted a "limit" system. Every draughtsman put upon his drawings—36 inches by 46 inches—eight numbers, the sheet was divided into eight different drawings, the original tracing was kept, and the blue-print was cut up along the margin lines, so that each machinist had only a little drawing, 11½ by 18 inches, of related parts to look at, with nothing but machining dimensions thereon, the original paper drawing alone bearing pattern maker's figures. The "limit" man receives every drawing from the draughtsmen, with nominal sizes on same, and he adds the limiting decimals for each class of fits, either above or below the line (see Fig. 244).

In regard to the shafts (see table) for all fits except "parallel" shafts and bushings, the holes are always changed, and the shafts remain standard in dimensions. We have had this system in operation now for about a year, and it works very well indeed.

*Mr. Stanley H. Moore.**—Owing to an unavoidable and deplorable lack of time the author is unable, at this writing, to give to the criticisms of his paper the attention which they require.

In reply to Mr. Riddell's criticism, the author wishes to state that in placing before us his deductions and the replies to his circular letter, he has added matter of considerable value to the discussion; however, the author does not stop to take up in detail his deductions and proposed chart, but calls the attention of the reader to the very instructive and significant replies from those who have to do with the assembling of cranks and shafts and fly-wheels under just the conditions which the author's curves assume. A dozen, more or less, believe his allowances to be too small; many are negative or evasive, while six or seven believe that his values would be "about right;" some few suggesting that the "structure of your armature" be such as to permit the use of greater allowances. One concern cites the practice of the Westinghouse people, stating that they use allowances on similar work which are considerably greater than those obtained from Mr. Riddell's chart, while another concern uses values for similar work that are three times those proposed.

---

* Author's Closure, under the Rules.

Mr. Riddell was evidently hasty in his reading of the author's sentence relative to the skill and experience required in the manipulation of forcing and shrinking fits. With the realization of the truth of his statement regarding the making of the fit, the author was careful to state that it is in the manipulation of shrinking fits that the greater skill is required.

To Mr. Calder's criticism of the values for forcing fits, the author will say, as he must likewise say to all other criticism presented, and as he has already said in closing the paper, that the values which he submitted were to be taken as a guide, and as indicative of the conditions which existed in the data which he was able to procure.

In closing, the author wishes to heartily thank all those who have given the time and labor necessary to discuss this important subject, and to further state again that, "As it is impossible for one individual to secure that amount of information from the thousands of progressive machine shops of this country, necessary to indicate the average American practice in this direction, the greatest value of this paper may still be found in its discussion by those who know, and again in its indication of what may be done with similar masses of seemingly chaotic data."

No. 997.*

THE EXPERIMENT BOILER OF THE OHIO STATE UNIVERSITY, WITH RESULTS OF SOME TRIALS.

BY E. A. HITCHCOCK, COLUMBUS, OHIO.
(Member of the Society.)

1. The purpose of this paper is not only for the presentation of a description of the Ohio State University Experimental Boiler Plant, which the writer believes will be of general interest, but to give to the Society some of the results that have been obtained from this installation by a series of trials of variable lengths, differing conditions and different kinds of coal.

Previous to the year 1901 at the Ohio State University, to carry on class work in boiler testing and to conduct boiler fuel trials, it was necessary to press into service one of the boilers of the University plant at such time as it was available and under the conditions existing. This was quite a serious drawback for experimental work in that there would necessarily be very little flexibility in the apparatus. The need of the University in this direction was brought to the attention of a well-known and honored member of this Society, Stillman W. Robinson, Emeritus Professor of Mechanical Engineering, who not only established the Department of Mechanical Engineering at Ohio State University and for many years was its head, but was the originator, I believe, of the first Mechanical Engineering Department in this country connected with a State university, that at Champaign, Ill. Although at the time Professor Robinson was not actively connected with the University, yet he retained such an active interest in its growth and welfare that he at once donated to the Institution a very complete outfit for boiler and fuel testing.

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

Description.

2. This equipment consists principally of a Babcock and Wilcox boiler, Green's fuel economizer, air heater, and Sturtevant induced and forced draft fans. The economizer, which is of the Green Fuel Company's standard make, has forty-eight 4½-inch diameter cast iron tubes, 9 feet long, put up in twelve sections of four tubes each, giving a total heating surface of 570 square feet. The scrapers of the economizer are run by a small independent engine located on top of the economizer. The air heater, Fig. 256, which was constructed in the Department of Mechanical Engi-

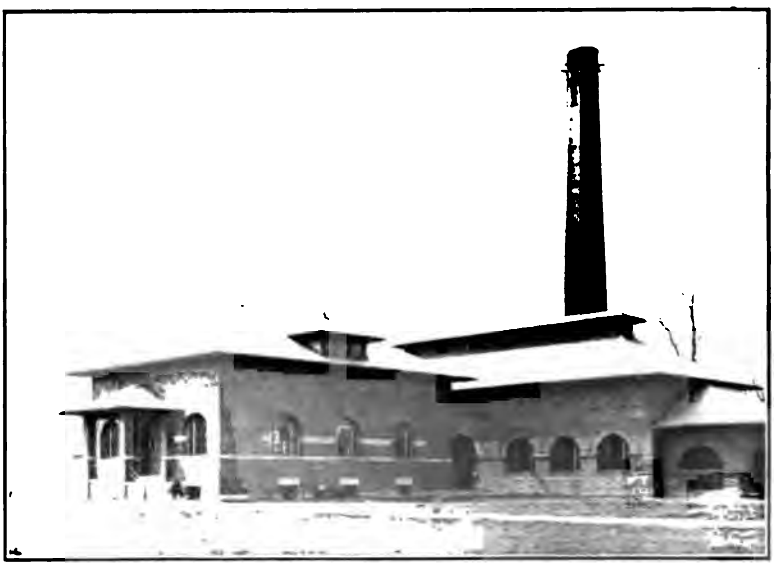


FIG. 245.

neering, is made of three hundred and fifty-one 2-inch tubes, 8 feet long, giving a heating surface of 1,330 square feet. The tubes used in its construction were condemned locomotive boiler tubes, light of weight but perfectly sound, consequently answering every purpose for an air heater. They were arranged staggered 2¼ inches vertical and 3 inches horizontal pitch expanded into the two tube sheets as shown. On account of the very irregular exterior surface of these tubes, the holes in the tube sheets were punched large enough to allow them to slip easily in place and consequently, in order to prevent tubes from fracturing when expanding them into place, it was necessary to use sheet iron liners around the tubes at the tube sheets. The length of the heater had to be such as to conform to the only available practical location, that is, just to the rear of the economizer. The boiler is of wrought steel construction throughout, built for a working pressure of 200 pounds, and has fifty-six 4-inch by 16-foot tubes and a 42-inch diameter drum, giving a heating surface of 1,070 square feet, or a builder's rating of 107 horse-power. The furnace is of the "Dutch oven" or fire brick arch type with stationary grates with an area of 25 square feet. The principal reason for selecting this size of boiler and type of furnace is that the one boiler in the University plant on which many trials have been conducted is of the same size, with the exception of the drum, but the furnace, however, is of the automatic stoker Murphy type, with fire brick arch, thereby enabling results to be obtained comparative of the two forms of furnaces, that is, hand firing versus automatic stoking. Even if the above conditions had not existed, the selection of the same type of furnace would have been made for the reason that the hand firing method is best suited for instruction work to students and for the general testing of all kinds and conditions of fuels, and also that, in the opinion of the writer, every boiler furnace—stoker or hand fired where bituminous coal is used—should have a fire brick arch extending the length of the grate bars, not only for the purpose of obtaining high furnace temperatures and more complete combustion, but because the boiler-heating surfaces should be protected from the gases while in the state of combustion, since there are many cases in practice where there has been heavy depreciation of the boiler-heating surfaces located directly over a fire of high rate of combustion with high volatile coals and the failures could be attributed to no other cause.

The induced and forced draft fans are the B. F. Sturtevant centrifugal steel plate type, that for the induced draft is their No. 70 48-inch wheel with 4-inch by 4-inch direct connected vertical engine, while that for forced draft is their No. 60 36-inch wheel with overhung pulley, belt driven by an independent compound engine. Both fans have their inner journals water cooled.

3. Before taking up the description of the arrangement of the apparatus, I wish to say in explanation to those to whom the question might occur of why such an arrangement was made, that

there was only one place available for the placing of the equipment, and that such place was very limited in floor space—consequently it can not be assumed that the best possible arrangement of such an equipment is that shown, but for this particular case it has been found, after nearly three years of service, to be very convenient for manipulation and experimentation.

4. The general arrangement of the testing plant is shown in Figs. 246, 247, 248 and 249. The furnace sets out in front so that the front of the bridge wall is on a line with the front of the boiler and the arch extending 1 foot 6 inches beyond the end of the grate bars, thereby leaving that space which in the ordinary setting is taken up with the grate bars free for experimentation by the insertion of fire brick deflectors, checker work, Kents "wing walls," etc. At the rear of the boiler is a 24-inch by 36-inch opening leading to the main boiler house flue, controlled by a vertical sliding damper. To the right at the rear are located the economizer and air heater. An 18-inch by 48-inch passage with vertical swinging damper connects the boiler and economizer. At the end of the economizer is a 1 foot by 9 foot 6 inch opening to air heater, and at end of air heater a 24-inch by 36-inch opening, controlled by sliding damper into main smoke flue. At the entering end of the air heater is an 18-inch by 48-inch opening connected by a breeching to the main flue—this opening is closed by means of a temporary brick wall at such times as the conditions of the trial demand. At the exit end of the air heater there is also an 18-inch by 48-inch opening in the wall between air heater and boiler, closed by a temporary brick wall. In the main boiler flue is a 24-inch by 36-inch damper for cutting off or regulating the natural draft produced by the boiler house chimney.

Near the junction of the boiler and economizer wall is a 24-inch by 24-inch opening in the floor, connecting into an underground brick flue passing beneath the economizer to the space below the air heater between the tube sheet and the air heater partition. On the other side of this partition, connecting into a chamber below the heater, is another brick duct leading to a $27\frac{1}{2}$-inch galvanized iron elbow connecting to the forced draft fan. This elbow can be very easily removed so that air can be taken direct from the boiler room without the intervention of the air heater. A $22\frac{3}{4}$-inch galvanized iron flue connects the fan with an opening under the furnace bridge wall, which has its outlet into the ash pit through a 17-inch by 29-inch opening controlled by a damper.

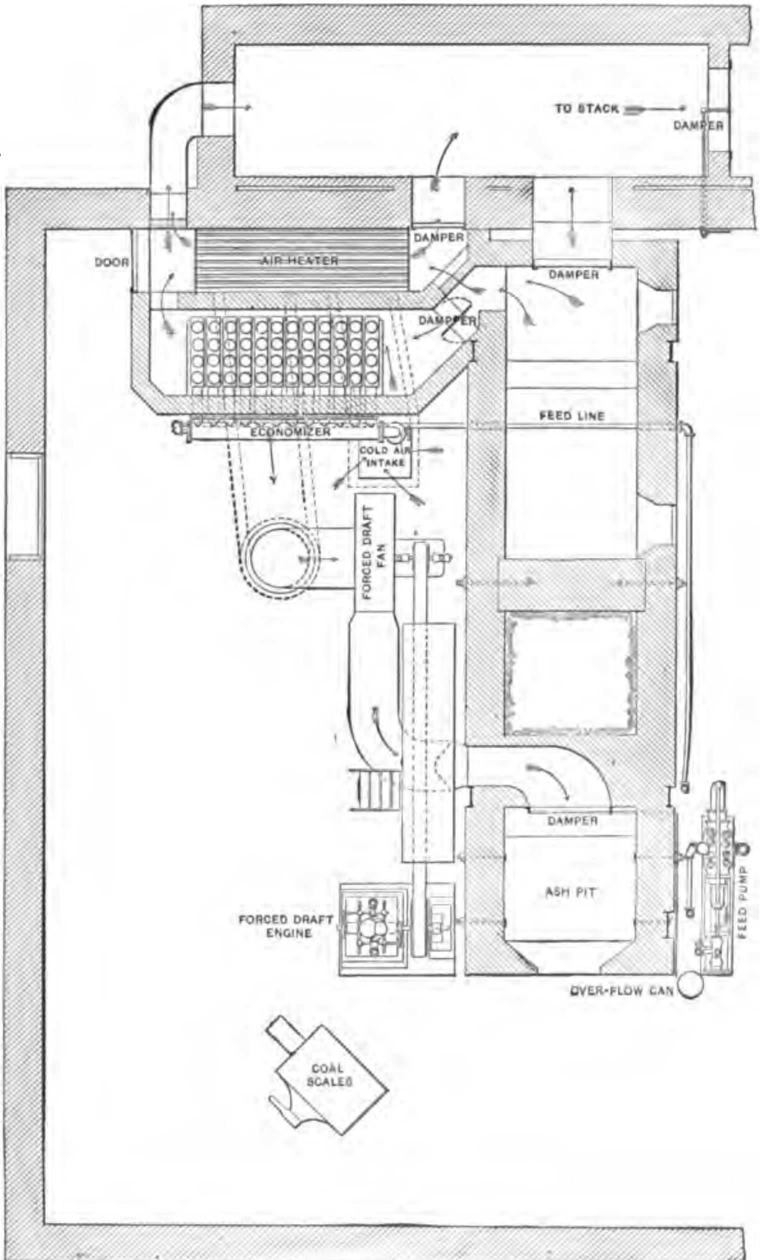

TO STACK
DAMPER
DAMPER
DOOR
AIR HEATER
DAMPER
DAMPER
FEED LINE
ECONOMIZER
COLD AIR INTAKE
FORCED DRAFT FAN
DAMPER
ASH PIT
FEED PUMP
FORCED DRAFT ENGINE
OVER-FLOW CAN
COAL SCALES
Hitchcock, E.A.

FIG. 246.

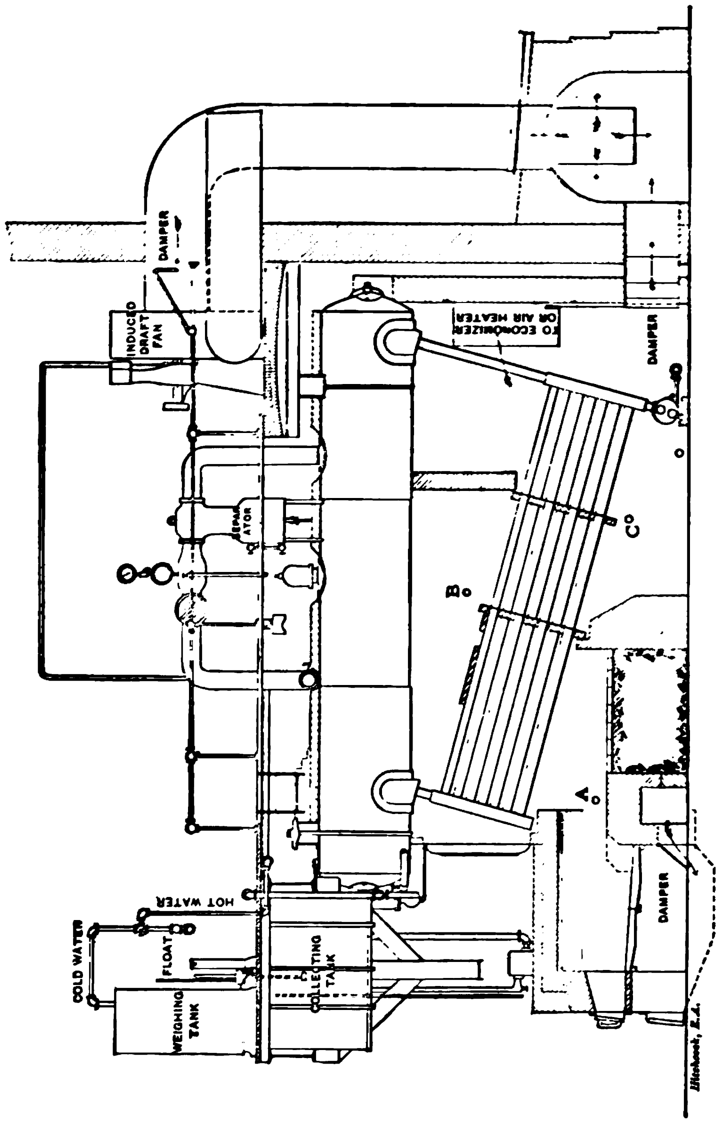

DAMPER
INDUCED DRAFT FAN
SEPARATOR
TO ECONOMIZER OR AIR HEATER
DAMPER
B
C
A
HOT WATER
COLD WATER
FLOAT
WEIGHING TANK
COLLECTING TANK
DAMPER

FIG. 247.

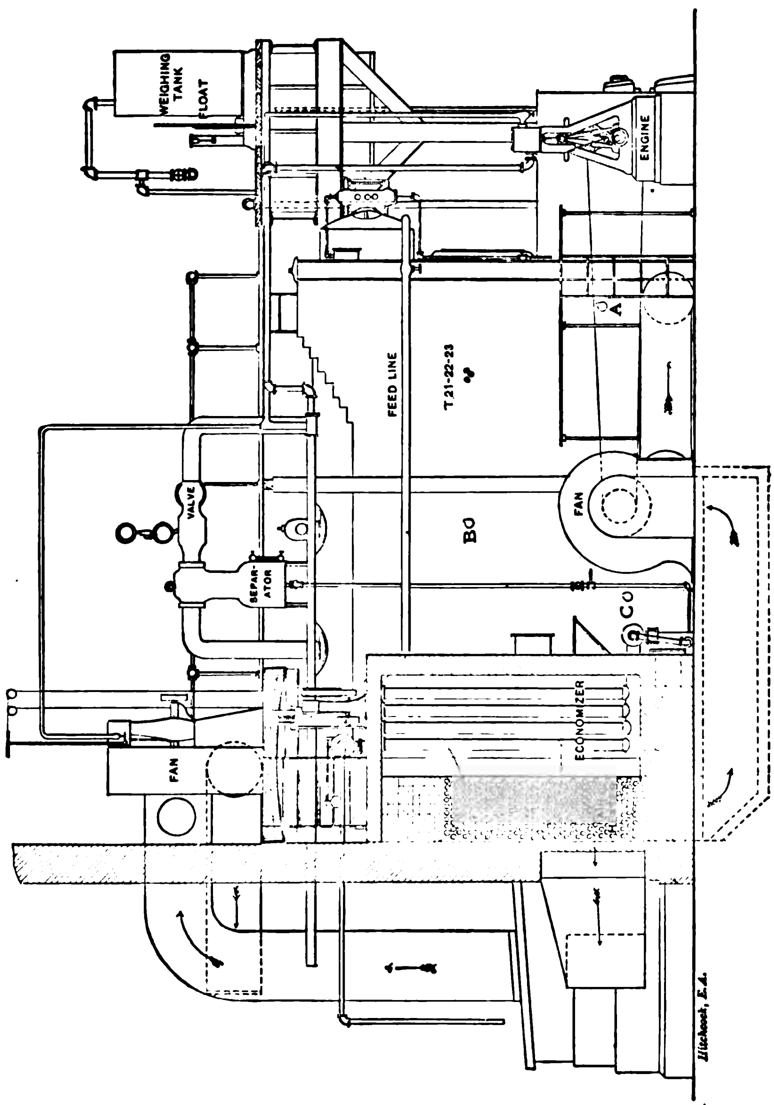

WEIGHING TANK
FLOAT
ENGINE
FEED LINE
T 21-22-23
A
FAN
BO
VALVE
SEPAR-ATOR
ECONOMIZER
FAN
Hitchcock, E.A.

FIG. 248.

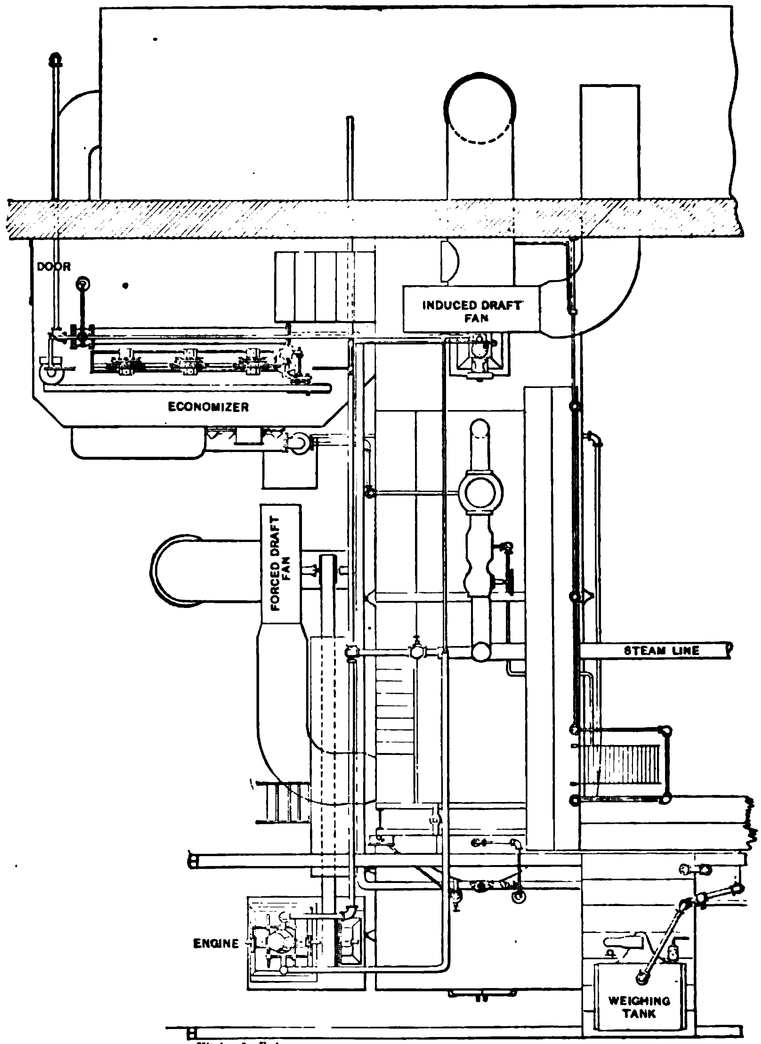


FIG. 249.

5. The induced draft fan is located above the boiler and to the rear, supported on a brick arch of 6 feet 6 inch span, sprung between two 10-inch channels held by six $\frac{3}{4}$-inch tie-rods. The whole rests on two 6-inch I.beams supported by the boiler house wall and the boiler channels. The point of support, however, on the boiler channels is directly over the boiler rear suspensions columns so as to avoid any transmission of engine vibration to the boiler, and this has been found to be the case with the engine running as high as 500 revolutions per minute.

A 30-inch iron duct connects the main smoke flue at the rear of the boiler with the fan which discharges the gases to the atmosphere through a $25\frac{3}{4}$-inch horizontal duct passing through the boiler house wall. The 30-inch flue has a swinging damper near its connection to the fan, this damper, of course, being closed when using natural draft.

6. Above and to the front of the boiler, supported by the I beams which support the coal conveying machinery and hoppers, is the water weighing tank and scales. This tank can be filled with either hot or cold water, has a capacity of 2,100 pounds, and opens through a quick opening valve into a collecting tank of 6,000 pounds capacity, suspended underneath. This collecting tank, which is covered, has two floats, one for use on ground floor as well as one on the platform, and also an overflow pipe extending vertically through the bottom of the tank to within two inches of the top. A pipe connects this overflow to a collecting can on the ground floor—for the collection of any water that might run out of the overflow while a test was in progress.

A Knowles 8-inch and 5-inch by 10-inch plunger pump is used for feeding, either direct into the boiler or by the way of the economizer. The feed line is so arranged that this pump with its accessories may be used for any other boiler in the plant. The steam line from the boiler has in it a 5-inch Stratton separator and a 5-inch extra heavy globe valve, conveniently located for manipulation so that the steam pressure on the boiler may be controlled regardless of that on the down side. There is also a 3-inch auxiliary line for the purpose of blowing steam into the atmosphere.

To guard against losses through the blow-off, there are two valves in the line and also a union between the valves where a blank flange may be inserted in case there is a possible leak through both valves.

To the front of the boiler drum, in addition to the regular water column with gauge cocks and glass, there is connected a Reliance high and low water alarm.

All steam and hot water piping is covered with Keasby and Mattison magnesia covering, the top of the economizer with magnesia blocking, and the sliding door in front of the air heater with their air cell paper. In bricking in the equipment there were no special features introduced in the way of special brick, air spaces, etc., since it was the purpose to have all things conform as near as possible to what universally prevails in practice.

7. From the arrangement shown and the description given, it will be seen that the principal possibilities for experimentation are as follows:

1. Boiler with natural draft.
2. Boiler with induced draft.
3. Boiler with forced dr.ft.
4. Boiler and economizer with natural draft.
5. Boiler and economizer with forced draft.
6. Boiler and economizer with induced draft.
7. Boiler, economizer and air heater with natural draft.
8. Boiler, economizer and air heater with induced draft.
9. Boiler, economizer and air heater with forced draft.
10. Boiler and air heater with natural draft, forced draft fan being used.
11. Boiler and air heater with induced draft, forced draft fan being used.
12. Boiler and air heater with strong induced draft alone.
13. Boiler with different grate areas under any of the above combinations.
14. Boiler, economizer and air heater, products of combustion, making two passes through the latter, lower and then upper half.
15. Boiler with different steam pressures from 0 to 200 pounds.

This equipment was installed under the supervision of Wm. C. McCracken, during April and May of 1900, but on account of the many details necessary for experimental work, was not completed until February of 1901. At this time, A. J. Boehme, G. R. Bott and J. S. Wilson, members of the senior class in Mechanical Engineering for graduation thesis, carried on under the direction of the writer a series of tests on this equipment for the purpose of determining principally the gain in efficiency, due to the economizer and air heater, and the efficiency of the plant as a whole.

Apparatus Employed.

8. Draft gauges were connected to the ash pit, to the combustion chamber back of the bridge wall, to the space at the end of boiler, to passages entering and leaving the economizer and to

space at the end of the air heater. The draft gauge at the end of the boiler was of the differential type, the liquids being alcohol and coal oil. Hohmann & Maurer mercurial pyrometers were used for obtaining flue gas temperatures leaving boiler and economizer. For obtaining the flue gas temperature at the end of the air heater, since it was impossible by means of a pyrometer to reach the proper point for obtaining such temperature, a thermometer was encased in an iron tube with side cut away for reading, the thermometer bulb being encased in a piece of brass $\frac{3}{4}$ inch diameter and $2\frac{1}{2}$ inches long, in order that the thermometer would remain constant for several seconds after removal from the flue.

9. Thermometers were used for taking the temperature of the air entering the air heater, on entering the elbow connected to the forced draft fan and on entering the ash pit, also the feed water on entering and leaving the economizer and on entrance to the boiler drum. Thermometers were also inserted in the boiler wall

FIG. 250.

at depths of three-quarters, one-half and one-quarter of its thickness, the three thermometers being within a radius of 3 inches and located, as shown in Fig. 248, 35 inches to the rear of and 62 inches below the top of the front suspension column.

10. Two pressure gauges were connected to the 5-inch line above the boiler, one above and one below the throttling valve, and also a Barrus calorimeter to the vertical line, $3\frac{1}{2}$ feet above the drum.

11. For analyzing flue gases, the Orsat apparatus was used, the sample being drawn continuously by means of either a water or steam aspirator through a $\frac{3}{4}$-inch sampling pipe, which in turn connects to the sampling tube extending across either the opening to the main smoke flue or the one to the economizer, as occasion demands. The form of sampling tube used is a $\frac{3}{4}$-inch pipe plugged at one end and has 1-16-inch holes 6 inches apart drilled along the side which faces down stream. This form of tube has

FIG. 251.

been found by Professor N. W. Lord to draw an average sample, and is the same form that has been in use by him and the writer for the past nine years. There is also connected to the boiler on a separate sampling line and tube, an Arndt Econometer, but this was not in use during the tests reported in this paper.

Fig. 250 shows the style of the oven furnace front, the only modification of same being a 3-inch hole covered with mica in one of the ash pit doors for the purpose of examining the fire when running under forced draft.

Fig. 251 shows a portion of the rear right-hand side of the boiler setting, with a Hofmann & Maurer pyrometer and a differential draft gauge in place. Just to the right of the draft gauge is shown a rope by means of which the speed of the induced draft fan is controlled. Also another device for opening and closing the natural draft damper.

Method Employed in Carrying on the Trials.

12. The boiler is fired continuously from thirty-six to forty-eight hours before the trial, in order that the setting should be thoroughly heated. About two hours previous to the commencing of the test proper, the fire is drawn, the damper being closed, the grate bars and ash pit cleaned, and a new fire immediately kindled with the coal to be used. This new fire, which always starts very rapidly on account of the hot fire brick arch, is brought as quickly as possible to the condition to be maintained throughout the trial, the draft being regulated to give the desired fuel consumption and depth of fire fixed to secure the best combustion with the least per cent. of air excess. The tubes are blown free of soot after starting the fire. About ten minutes before starting the test proper, the exact time being noted, the last fresh coal is thrown on and five minutes later the fire is leveled with a rake and the thickness determined by resting a bar on the bed of fire and leveling same by sighting on a level gauge and then noting the height by graduations on the fire door which is open just enough to allow the rod to pass into the furnace. This method, the writer believes, is much more accurate than gauging by the eye, which is quite impossible for any degree of accuracy with this style of furnace and high volatile coals. At time for starting, the feed-water is brought up to the overflow point in the lower collecting tank (the pump having been closed down) and the height of water in the boiler drum noted on a scale reading in 1-10 inch fastened to the gauge glass. A string is also put on the glass at the same point simply as a guide for the person controlling the feed water to the boiler. All readings are taken at regular intervals of one-half hour, commencing fifteen minutes after the test starts. The firing is done at regular intervals of from three to five minutes, depending upon the rate of combustion, and the amount fired is usually two shovelfuls. The fuel is brought to the boiler in a borrow, the time for consuming each load being noted. At the time of filling each barrow, about one-half shovelful is taken, not from the barrow but from that point in the pile where the coal in the barrow had been taken, and the total quantity so collected during the trial is reduced for analysis by the process of quartering.

13. If the coal was such that it was necessary to clean the fires

during the trial, this was always done at such a time that the period between the time of cleaning and the end of the trial would be practically the same as that between the time of starting the new fire and the starting of the test, thereby giving a clean fire at the end as well as at the beginning of the trial. At the end of the test the same methods are employed as regards firing, the thickness of fire, etc., as at the beginning and if the water in the boiler is not the same height by the scale, the necessary correction is made for this based on a calibration of the boiler drum. Also a correction for a different thickness of fire is made, but this has very seldom been found necessary, since with care on the part of the fireman and the use of the fire gauge, the thickness can easily be governed to within ½ inch of the thickness at start. The fire is then allowed to burn out when all refuse is cleaned from the grates and the pit. From all the refuse obtained, the clinker is sorted, thereby giving per cent. of clinkers to coal and in sampling the refuse for analysis, proportionate amounts by weight of clinker and refuse are taken, broken up and then quartered.

14. The first three trials, Nos. 101, 102 and 103 (Table 1) were made with George's Creek Cumberland coal, furnished by the Baltimore and Ohio R. R. Co., the only practical difference between the trials being that they were run under different rates of combustion for the purpose of determining approximately the rate to give the best all-round results. For these runs the entire plant, that is, boiler, economizer and air heater were in use, designated by the letters BEH written after the number of the trial. This work also familiarized those taking the active part with the apparatus and its manipulation.

Trials Nos. 104, 106, 116 and 117 (Tables 2 and 3) were made with Pocahontas lump coal, furnished by Castner, Curren & Bullitt of Philadelphia. Trial No. 104 is with economizer and No. 106 without, while trial No. 116 is with economizer and air heater and No. 117 is with air heater only cut out.

TABLE I.

Kind of fuel : Georges Creek, Cumberland

State of weather	Stormy	Cloudy	Cloudy
Date of trials ... 1901	Feb. 2	Feb. 9	Feb. 16
Duration of trials ... hours	10	10	8
Number of trial	101 BEH	102 BEH	103 BEH

Average Pressures.

Steam pressure by gage ... lbs. per sq. in.	134.	136.	136.1
Atmospheric pressure by barometer .. ins. mercury	29.64	29.06	28.9
Absolute steam pressure ... lbs. per sq. in.	148.6	150.3	150.4
Force of draft between damper and boiler ... ins. water	.16	.19	.234
Force of draft leaving economizer .. "	.21	.232	.258
" " " air heater .... "	.227	.257	.273
" " or blast in ash pit .... "	+.08	+.035	+.088

Average Temperatures.

External air ... deg. Fahr.	26.	25.	34.6
Fire room ... "	70.	66.4	75.3
Feed water entering economizer ... "	51.4	50.7	52.4
" " " boiler ... "	166.	156.1	158.6
Escaping gases from boiler ... "	490.	502.	575.
" " " economizer ... "	311.	323.	358.
" " " air heater .... "	234.	256.	283.
Air entering ash pit ... "	158.5	163.	170.

Fuel.

Size and condition		Run of mine	
Method of firing		Spreading	
Total weight of coal fired ... lbs.	4,490	5,610	5,503
Weight of coal fired during test ... "	3,750	5,027	4,773
Percentage of moisture in coal by analysis ... per cent.	1.08	1.08	1.08
Weight of dry coal consumed during test ... lbs.	3,710	4,972	4,721
Total ash and refuse ... "	401.5	429.5	491.
Combustible consumed during test computed from analysis of refuse ... "	3,405	4,523	4,207
Weight of clinker from total coal ... "	63.5	47.5	50.
Percentage of ash and refuse to coal .. per cent.	8.9	7.6	11.2
" clinker to coal ... "	1.4	.85	.91

TABLE I.—*Continued.*

PROXIMATE ANALYSIS OF COAL.

Fixed carbon	per cent.	73.84	73.84	73.84
Volatile matter	"	17.93	17.93	17.93
Moisture	"	1.08	1.08	1.08
Ash	"	7.15	7.15	7.15

ULTIMATE ANALYSIS OF COAL.

Carbon	per cent.	82.64	82.64	82.64
Hydrogen	"	4.25	4.25	4.25
Oxygen	"	4.57	4.57	4.57
Nitrogen	"	.56	.56	.56
Sulphur	"	.83	.83	.83
Ash	"	7.15	7.15	7.15

ANALYSIS OF ASH AND REFUSE.

Ash	per cent.	88.60	81.10	67.88
Volatile combustible	"	11.40	18.90	32.12

FUEL PER HOUR.

Coal consumed per hour	lbs.	375	502	596
Combustible consumed per hour	"	340	452	526
Coal per square foot of grate per hour	"	14.8	20	23.6
Combustible per square foot of heating surface per hour	"	.317	.422	.490

CALORIFIC VALUE OF FUEL.

Calorific value per pound of actual coal by Mahler Calorimeter	B. T. U.	14,240	14,240	14,240
Calorific value per pound of dry coal	"	14,395	14,395	14,395
Calorific value per pound of combustible	"	15,518	15,518	15,518

QUALITY OF STEAM.

Percentage of moisture in steam	per cent.	.8	.83	.8
Quality of steam (dry steam = unity)	"	.992	.9917	.992
" Correction	"	.9936	.9934	.9936

TABLE I.—*Continued.*

Water.

Total weight of water fed to boiler ....lbs.	32,836	45,239	41,299
" " " " economizer .. "	32,914	45,615	41,328
Equivalent weight of water actually evaporated into dry steam.................. "	32,625	44,940	41,034
Factor of evaporation for boiler .... "	1.094	1.105	1.102
Factor of evaporation for boiler and economizer .... "	1.212	1.214	1.212
Equivalent water evaporated into dry steam from and at 212 degrees for boiler...... "	35,691	49,660	45,220
Equivalent water evaporated into dry steam from and at 212 degrees for economizer "	3,907	4,976	4,588
Equivalent water evaporated into dry steam from and at 212 degrees for boiler and economizer .... "	39,598	54,636	49,808

Water per Hour.

Equivalent evaporation per hour from and at 212 degrees for boiler ....lbs.	3,569	4,966	5,652
Equivalent evaporation per hour from and at 212 degrees for economizer......... "	390	497	573
Equivalent evoporation per hour from and at 212 degrees —total .... "	3,959	5,463	6,225
Equivalent evaporation per hour from and at 212 degrees per sq. ft. boiler heating surface .... "	.333	.463	.528

Horse-Power.

Builders rated horse-power	107	107	107
Horse-power developed by boiler	103.4	143.9	163.8
Horse-power developed —total	114.7	158.3	180.3

Economic Results.

Water apparently evaporated under actual conditions per pound of coal as fired...lbs.	8.756	9.000	8.653
Equivalent evaporation from and at 212 degrees per pound of coal—for boiler .. "	9.518	9.879	9.474
Equivalent evaporation from and at 212 degrees per pound of dry coal—for boiler .... "	9.625	9.988	9.578
Equivalent evaporation from and at 212 degrees per pound of coal, for system .. "	10.684	10.992	10.550
Equivalent evaporation from and at 212 degrees per pound of combustible, for boiler .... "	10.496	10.980	10.748

TABLE I.—*Continued.*

EFFICIENCY.

Efficiency of boiler and grate ....per	cent.	64.54	66.99	64.24
" "	"	65.30	68.33	66.88
" of system	"	72.46	74.59	71.54

ANALYSIS OF FLUE GAS.

		Vol.	Wt.	Vol.	Wt.	Vol.	Wt.
CO_2 Carbon dioxide ....per	cent.	8.82	13.65	10.58	15.55	11.5	16.84
O Oxygen	"	10.04	10.75	8.48	9.00	6.71	7.11
CO Carbon monoxide	"	.44	.41	.67	.62	1.38	1.27
N Nitrogen	"	80.70	75.79	80.27	74.83	80.41	74.7
Percentage of air excess	"	89.75		66.91		46.41	
Pounds of air used per pound of coal .		19.41		17.17		14.36	

HEAT BALANCE.

	B.T.U.	%	B.T.U.	%	B.T.U.	%
Loss per lb. of coal due to products combustion	927	6.5	940	6.6	926	6.5
" " " " " air excess........	737	5.2	554	3.9	370	2.6
" " " " " latent heat.......	401	2.8	399	2.8	341	2.4
" " " " " unburned coal....	141	1.	256	1.8	512	3.6
" " " " " CO..............	407	2.9	513	3.6	826	5.8
" " " " " radiation, etc.....	2,435	17.1	2,037	14.3	2,123	14.9
Heat used in evaporation..................	9,192	64.5	9,541	67.0	9,142	64.2
Total heat supplied......................	14,240	100.	14,240	100.	14,240	100.

TABLE 2.

Kind of fuel: Pocahontas.

State of weather		Clear	Stormy
Date of trials	1901	Feb. 22	Feb. 23
Duration of trials...	hours	10	10
Number of trial..		104 BE	106 B

AVERAGE PRESSURES.

Steam pressure by gage.....................	lbs. per sq. in.	138.4	137
Atmospheric pressure by barometer..........	ins. mercury	29.3	30
Absolute steam pressure	lbs. ber sq. in.	153	151.8
Force of draft between damper and boiler	ins. water	.257	.233
" " leaving economizer	"	.272	....
" " " air heater	"	....	....
" " or blast in ash pit	"	....	....

TABLE 2.—*Continued.*

AVERAGE TEMPERATURES.

External air	deg. Fahr.	15	17.9
Fire room	"	61.3	69.8
Feed water entering economizer	"	49.9	......
" " " boiler	"	165	52.5
Escaping gases from boiler	"	560	603
" " " economizer	"	360	......
" " " air heater	"	......	......
Air entering ash pit	"	......	......

FUEL.

Size and condition		Lump	
Method of firing		Spreading	
Total weight of coal fired	lbs.	6,213	6,291
Weight of coal fired during test	"	5,709	5,532
Percentage of moisture in coal by analysis	per cent.	.95	.95
Weight of dry coal consumed during test	lbs.	5,665	5,480
Total ash and refuse	"	340	278
Combustible consumed during test computed from analysis of refuse	"	5,266	5,144
Weight of clinker from total coal	"	90	43
Percentage of ash and refuse to coal	per cent.	5.47	4.41
" clinker to coal	"	1.44	.68

PROXIMATE ANALYSIS OF COAL.

Fixed carbon	per cent.	76.88	76.88
Volatile matter	"	18.68	18.68
Moisture	"	.95	.95
Ash	"	3.49	3.49

ULTIMATE ANALYSIS OF COAL.

Carbon	per cent.	87.75	87.75
Hydrogen	"	4.34	4.34
Oxygen	"	2.93	2.93
Nitrogen	"	.88	.88
Sulphur	"	.61	.61
Ash	"	3.49	3.49

ANALYSIS OF ASH AND REFUSE.

Ash	per cent.	52.09	59.05
Volatile combustible	"	47.91	40.95

TABLE 2.—*Continued.*

Fuel per Hour.

Coal consumed per hour	lbs.	571	553
Combustible consumed per hour	"	526	514
Coal per square foot of grate per hour	"	22.8	22.1
Combustible per square foot of heating surface per hour	"	.491	.480

Calorific Value of Fuel.

Calorific value per pound of actual coal by Mahler Calorimeter	B. T. U.	15,053	15,053
Calorific value per pound of dry coal	"	15,196	15,196
" " " combustible	"	15,752	15,752

Quality of Steam.

Percentage of moisture in steam	per cent.	.77	.73
Quality of steam (dry steam — unity)	"	.9923	.9927
" Correction	"	.9940	.9940

Water.

Total weight of water fed to boiler	lbs.	52,561	48,138
" " " " economizer	"	53,510	....
Equivalent weight of water actually evaporated into dry steam	"	52,480	47,850
Factor of evaporation for boiler		1.096	1.212
" " " and economizer		1.2165	....
Equivalent water evaporated into dry steam from and at 212 degrees for boiler	lbs.	57,520	58,030
Equivalent water evaporated into dry steam from and at 212 degrees for economizer	"	6,400	....
Equivalent water evaporated into dry steam from and at 212 degrees for boiler and economizer	"	63,920	....

Water per Hour.

Equivalent evaporation per hour from and at 212 degrees for boiler	lbs.	5,752	5,803
Equivalent evaporation per hour from and at 212 degrees for economizer	"	640	....
Equivalent evaporation per hour from and at 212 degrees—total	"	6,392	....
Equivalent evaporation per hour from and at 212 degrees per sq. ft. boiler heating surface	"	5.37	5.42

TABLE 2.—*Continued.*

Horse-power.

Builders rated horse-power	107	107
Horse-power developed by boiler	166.7	168.2
" " total	185.2	....

Economic Results.

Water apparently evaporated under actual conditions per pound of coal as fired ... lbs.	9.207	8.745
Equivalent evaporation from and at 212 degrees per pound of coal—for boiler ... "	10.076	10.481
Equivalent evaporation from and at 212 degrees per pound of dry coal—for boiler ... "	10.154	10.580
Equivalent evaporation from and at 212 degrees per pound of coal, for system ... "	11.207	....
Equivalent evaporation from and at 212 degrees per pound of combustible, for boiler ... "	10.923	11.475

Efficiency.

Efficiency of boiler and grate ... per cent.	64.56	67.23
" " ... "	66.89	69.09
" of system ... "	71.88	....

Analysis of Flue Gas.

	Vol.	Wt.	Vol.	Wt.
CO_2 Carbon dioxide ... per cent.	10.82	15.88	11.88	17.28
O Oxygen ... "	7.78	8.26	7.11	7.55
CO Carbon monoxide ... "	.23	.21	.09	.08
N Nitrogen ... "	81.17	75.65	80.92	75.09
Percentage of air excess ... "	57.24		50.39	
Pounds of air used per pound of coal ...	17.33		16.98	

Heat Balance.

	B.T.U.	%	B.T.U.	%
Loss per pound of coal due to products combustion ...	1,460	9.7	1,595	10.6
" " " " air excess ...	753	5.0	723	4.8
" " " " latent heat ...	406	2.7	406	2.7
" " " " unburned coal ...	497	3.3	376	2.5
" " " " CO ...	181	1.2	....	.....
" " " " radiation, etc. ...	2,032	13.5	1,832	12.2
Heat used in evaporation ...	9,724	64.6	10,121	67.2
Total heat supplied ...	15,053	100.	15,053	100.

TABLE 3.

Kind of fuel : Pocahontas.

State of weather		Hazy	Clear
Date of trials	1901	May 14	May 15
Duration of trials	hours	10	10
Number of trials		116 BEH	117 BE

Average Pressures.

Steam pressure by gage	lbs. per sq. in.	96.	98.7
Atmospheric pressure by barometer	ins. mercury.	29.36	29.42
Absolute steam pressure	lbs. per sq. in.	110.4	113.1
Force of draft between damper and boiler	ins. water	.165	.168
" " leaving economizer	"	.171	.174
" " " air heater	"	.199	......
" " or blast in ash pit	"	+.078	......

Average Temperatures.

External air	deg. Fahr.	69.	66.
Fire room	"	91.8	89.4
Feed water entering economizer	"	60.	59.5
" " " boiler	"	151.4	148.8
Escaping gases from boiler	"	499.	470.
" " " economizer	"	314.	297
" " " air heater	"	248.	.....
Air entering ash pit	"	174.	59.3

Fuel.

Size and condition		Lump	
Method of firing		Spreading	
Total weight of coal fired	lbs.	4,921	4,876
Weight of coal fired during test	"	4,024	4,061
Percentage of moisture in coal by analysis	per cent.	1.16	1.2
Weight of dry coal consumed during test	lbs.	3,977	4,012
Total ash and refuse	"	200	251
Combustible consumed during test computed from analysis of refuse	"	3,755	3,785
Weight of clinker from total coal	"	71	91
Percentage of ash and refuse to coal	per cent.	4.07	5.15
" clinker to coal	"	1.44	1.86

Proximate Analysis of Coal.

Fixed carbon	per cent.	76.88	76.15
Volatile matter	"	18.45	18.45
Moisture	"	1.16	1.20
Ash	"	3.51	4.00

TABLE 3.—*Continued.*

ULTIMATE ANALYSIS OF COAL.

Carbon	per cent.	87.73	87.39
Hydrogen	"	4.34	4.27
Oxygen	"	2.93	2.87
Nitrogen	"	.88	.87
Sulphur	"	.61	.60
Ash	"	3.51	4.00

ANALYSIS OF ASH AND REFUSE.

Ash	per cent.	64.21	72.20
Volatile combustible	"	35.79	27.80

FUEL PER HOUR.

Coal consumed per hour	lbs.	402	406
Combustible consumed per hour	"	375	378
Coal per square foot of grate per hour	"	20.1	20.3
Combustible per square foot of heating surface per hour	"	.351	353

CALORIFIC VALUE OF FUEL.

Calorific value per pound of actual coal by Mahler Calorimeter	B. T. U.	15,033	14,933
Calorific value per pound of dry coal	"	15,209	15,115
" " " combustible	"	15,769	15,735

QUALITY OF STEAM.

Percentage of moisture in steam	per cent.	.62	.70
Quality of steam (dry steam = unity)	"	.9938	.993
" Correction	"	.9947	.9941

WATER.

Total weight of water fed to boiler	lbs.	42,181	39,512
" " " " economizer	"	42,701	40,099
Equivalent weight of water acually evaporated into dry steam	"	41,958	39,280
Factor of evaporation for boiler		1.1032	1.1052
" " " and economizer		1.1978	1.1973
Equivalent water evaporated into dry steam from and at 212 degrees for boiler	lbs.	46,290	43,415
Equivalent water evaporated into dry steam from and at 212 degrees for economizer	"	4,039	3,696
Equivalent water evaporated into dry steam from and at 212 degrees for boiler and economizer	"	50,329	47,111

TABLE 3.—*Continued.*

Water per Hour.

Equivalent evaporation per hour from and at 212 degrees for boiler . . . . . lbs.	4,629	4,341
Equivalent evaporation per hour from and at 212 degrees for economizer . . . . . "	404	369
Equivalent evaporation per hour from and at 212 degrees—total . . . . . "	5,033	4,711
Equivalent evaporation per hour from and at 212 degrees per sq. ft. boiler heating surface . . . . . "	4.31	4.05

Horse-power.

Builders rated horse-power	107	107
Horse-power developed by boiler	134.1	125.8
" " —total	145.8	136.5

Economic Results.

Water apparently evaporated under actual conditions per pound of coal as fired . . . . . lbs.	10.482	9.732
Equivalent evaporation from and at 212 degrees per bound of coal—for boiler . . . . . "	11.503	10.690
Equivalent evaporation from and at 212 degrees per pound of dry coal—for boiler . . . . . "	11.640	10.821
Equivalent evaporation from and at 212 degrees per pound of coal, for system . . . . . "	12.507	11.589
Equivalent evaporation from and at 212 degrees per pound of combustible, for boiler . . . . . "	12.327	11.470

Efficiency.

Efficiency of boiler and grate . . . . . per cent.	73.84	69.12
" " . . . . . "	75.50	70.31
" of system . . . . . "	80.28	75.00

Analysis of Flue Gas.

	Vol.	Wt	Vol.	Wt.
CO_2 Carbon dioxide . . . . . per cent.	13.17	19.19	13.11	19.02
O Oxygen . . . . . "	5.64	5.95	5.86	6.16
CO Carbon monoxide . . . . . "	.17	.16	.44	.43
N Nitrogen . . . . . "	81.02	74.70	80.59	74.39
Percentage of air excess	36.15		38.13	
Pounds of air used per pound of coal	15.27		15.30	

TABLE 3.—*Continued.*

HEAT BALANCE.

	B.T.U.	%	B.T.U.	%
Loss per pound of coal due to products combustion......	962	6.4	1,208	8.1
" " " " air excess	316	2.1	418	2.8
" " " " latent heat	406	2.7	408	2.7
" " " " unburned coal	301	2.0	239	1.6
" " " " CO	129	.8	318	2.1
" " " " radiation, etc.............	1,819	12.1	2,032	13.6
Heat used in evaporation	11,100	73.8	10,320	69.1
Total heat supplied	15,033	100.	14,933	100.

15. For the two latter trials the grate area was reduced to 20 square feet, as is also for all following trials except No. 167. From this series of seven trials, the gain due to the economizer, both as to capacity and economy, may readily be seen, and for the air heater the theoretical gain may be computed on trials Nos. 101, 102 and 103, but the actual practical gain is shown by analyzing trials Nos. 116 and 117, which for running conditions are practically identical. As will be seen, the coal burned per square foot of grate per hour is practically identical in each case as is the draft and air per pound of coal. As the gain due to the economizer is practically the same in each case, that is 8.7 and 8.5 per cent., the difference in evaporation for the plant is not due to the air heater alone but to several causes, as shown by the heat balance. To the air heater only can be attributed that per cent. of gain which is shown by the difference of losses due to products of combustion and air excess of one test over the other, or 2.4 per cent for the trials in question. It will be observed throughout the series of trials given in this paper that the heat balance differs slightly in form from that adopted by the Society. The principal reason for holding to this form is that it was adopted by Professor N. W. Lord many years ago and has been in use by him and the writer during the past nine years in all boiler and fuel testing, therefore the form would naturally be held to more especially for the purpose of comparison with all work that has gone before. For assistance rendered and many valuable suggestions given, we are greatly indebted to Professor N. W. Lord, in whose department all the chemical work was carried on and calorific determinations of the coals made.

16. In all the trials, the refuse obtained is for the total coal

burned from the time of starting the fire, the grates and ash pit being thoroughly cleaned before and after each trial. The combustible is computed from the analysis of this refuse. In all cases except No. 101 the combustible indicates, as is expected, the passage of ash beyond the bridge wall and that case showing the opposite result is unquestionably due to imperfect sampling of the refuse.

From the heat balances it will be seen that the "radiation, etc., or unaccountable loss" varies from 12.1 per cent. up to 17.1 per cent., the latter value being for trial 101, for all others this loss ranges below 15 per cent.

17. In view of the loss of ash over the bridge wall, as determined by analysis of refuse and the great unaccountable losses shown by the heat balance not only on these tests but on a great many other previous trials covering a tasting period of nine years, it was decided to run a series of trials by means of which could be determined:

First. The percentage of refuse passing the bridge wall and collecting throughout the boiler, and what percentage of such refuse to be combustible matter.

Second. What effect a trial would have on the "unaccounted loss" in the heat balance, starting with cold boiler walls.

Third. The length of time in continuous running for the boiler walls to become saturated with heat, their temperatures remaining constant.

Fourth. The number of hours the boiler should be in continuous service before starting a trial.

Fifth. The accuracy of six-hour trials in comparison with those of ten and twelve hours' duration.

To obtain these facts, the plan of operation was to first clean the boiler, furnace and setting thoroughly throughout. The trial to start with the boiler cold and at the time of kindling the fire, and to continue until the temperature of the boiler walls at the special point where the temperature was taken became practically constant. To maintain as near as possible the same conditions throughout as to coal burned per hour, intensity of draft, etc., and to divide the whole run into trials of six hours' duration, two in combination making trials of twelve hours, and at the last, when constant conditions were reached, to end with a ten hour trial. At the end of the run to shut the boiler down and again clean out the setting thoroughly.

18. This experimental work was taken in hand and very ably

carried on as thesis work by Messrs. W. A. Johnson, W. B. Morris, G. T. Frankenberg and A. E. Wellbaum, members of the 1902 Senior Class in Mechanical Engineering.

Pocahontas coal of the same shipment as that of the previous trials was used. The same methods were employed for carrying on the trials as on the former run. It was found on the former trials that one pyrometer at the end of the economizer, passing through the wall midway between top and bottom of economizer, did not give the average temperature of the escaping gases, but a much higher result; therefore, to get nearer that average, two pyrometers were used, passing through the economizer wall at one quarter distances from top and bottom. The firing in this series was done by Messrs. E. G. Bailey and R. E. Rightmire, senior students in mechanical engineering and skilled in this line of work—all other trials reported in this paper with the exception of No. 167 were fired by Mr. E. G. Bailey.

19. In order to be able to compute the equivalent evaporation for the first six hours of the trial, during which time steam was being raised, the water capacity of both boiler and economizer was determined several days previous to the trial, and the temperature of that water which had been standing in the boiler taken at the time of starting the run.

The times of the principal events for the 76 hour trial are as follows:

TABLE 4.

No. of trial.	Starting time.			
134	3 P.M.	Boiler steaming................3.40 P.M.		
		Boiler cut in ....4.20 "		
		Steam pressure..................95 lbs.		
		FIRE.		
		Sliced.	Cleaned.	Tubes blown.
135	9 P.M.	2. A.M.	....	....
136	3 A.M.	5.30 "	....	6.30 A.M.
137	9 "	....	1.55 P.M.	....
138	3 P.M.	12. "	....	....
139	9 "	12. "	....	....
140	3 A.M.	6. "	....	6.45 A.M.
141	9 "	10.20 "	11.45 P.M.	....
142	3 P.M.	....	....	....
143	9 "	12.50 "	....	....
144	3 A.M.	6.30 "	8.45 A.M.	....
145	9 "	....	....	....

20. At the end of the trial the boiler setting was again thoroughly cleaned. The amount of refuse obtained, with their per

cent. of combustible matter, is in a table of results which on account of its extent is not published in the paper.* The points sought by this series of trials are as follows:

First. As will be seen, the total dry coal consumed from time of starting the trial was 33,209 pounds. Computing the combustible in the usual way, there would be 31,861 pounds as against 31,644 pounds as computed from an analysis of the refuse in the ash pit. Throughout the boiler there was collected 142 pounds of refuse, or 9½ per cent. of the total, making a total refuse of 1,490 pounds, thus giving for the combustible consumed 31,719 pounds, which is a very small percentage in excess of the combustible matter computed from analysis of refuse, thereby indicating, as is expected, the passing of refuse beyond the boiler into the flue. The amount of this refuse passing the bridge wall has been found by the writer to be dependent upon the intensity of the draft and the thickness of the fire, for in a series of trials with practically the same kind of coal, with thickness of fire ranging from 6½ to 7½ inches and the draft averaging .18 inches, there was collected on a plate one foot square, located at rear of boiler between it and the flue, an average of .6 of a gram per hour, while a trial with .56 inches draft and a 5½-inch fire gave on the same plate 7.1 gram per hour, which would indicate that the error introduced in computing the combustible from the quantity of refuse in the ash pit would be increased with the intensity of the draft, and therefore all evaporations per pound of combustible, where the combustible is taken as the difference between the dry coal and the refuse, can not be strictly accurate.

Second. The heat balance of trials Nos. 134, 135 and 136 show that the cold boiler walls increased the "unaccountable loss" some 8.5 per cent and that this loss has reached its average at the end of about 18 hours.

Third. The wall temperature curves, Fig. 252, show that even after 76 hours of continuous running the walls are not completely saturated with heat, the curves not having reached the horizontal, although nearly so.

Fourth. The heat balances indicate that for accurate results a boiler with this type of setting should be run continuously for

* On account of the expense involved the Society refrains from the tables of trials Nos. 134 to 145 and Nos. 165, 166 and 167, therefore a print of such tables will be furnished to those interested on application to the writer.

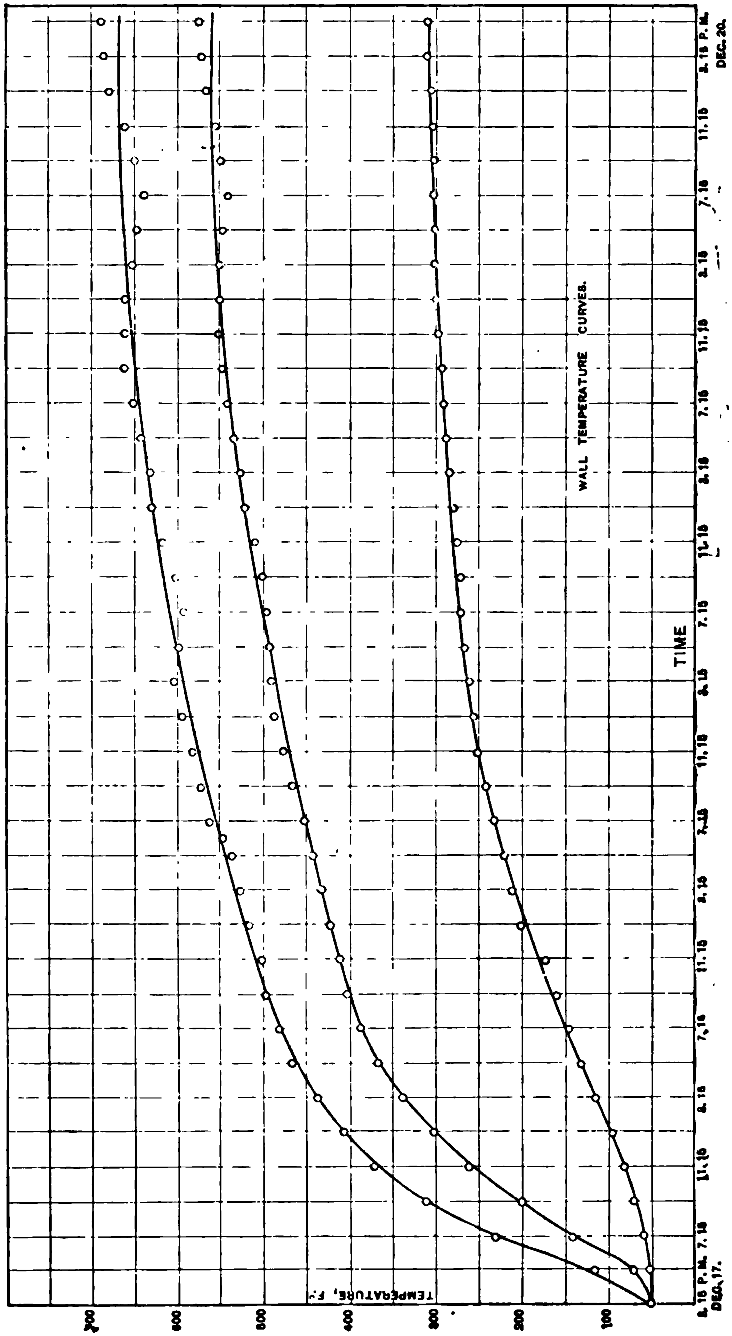

WALL TEMPERATURE CURVES.
TIME
TEMPERATURE, F.
700
600
500
400
300
200
100
3.15 P.M. DEC. 17.
3.15 P.M. DEC. 20.

FIG. 252.

at least thirty hours before a trial of fuel or of the boiler is commenced.

Fifth. Table 5 gives the principal items of the several runs,

TABLE 5.

Duration of trial .... hrs.	12	12	12	12	12	10
Number of trial	135 & 136	137 & 138	139 & 140	141 & 142	143 & 144	145
Steam pressure by gage .... lbs.	96.7	97.5	96.7	97.9	98.45	98.5
Force of draft between damper and boiler .... ins.	.239	.228	.234	.222	.206	.225
Force of draft leaving economizer .... "	.303	.297	.310	.295	.292	.298
Temperature feed water entering economizer .... Fahr.°	52.5	51.2	52.2	50.9	50.1	51.1
Temperature feed water entering boiler .... "	157.2	153.1	157	152.2	154.7	154.3
Temepature escaping gases from boiler .... "	474	500	515	515	515	541.6
Temperature escaping gases leaving economizer, upper pyrometer .... "	317.5	333.6	339	341.3	341.7	354.4
Temperature escaping gases leaving economizer, lower pyrometer .... "	285.3	298	303.8	306.5	304.6	317.8
Coal per square-foot grate per hour .... lbs.	21.11	22.6	20.87	22.73	20.51	22.51
Horse-power developed for boiler and economizer	142.3	154	145	156	142.2	155.9
Horse-power developed for boiler	130	140.3	132	142.4	129.4	142.1
Equivalent evaporation from and at 212 degrees per pound of coal for boiler and economizer .... lbs.	11.68	11.75	12.00	11.84	11.96	11.96
Equivalent evaporation from and at 212 degrees per pound of coal for boiler .... "	10.62	10.71	10.91	10.80	10.89	10.89
Efficiency of boiler figured from combustible .... per cent.	68.78	69.36	70.7	70.00	70.58	70.7
Efficiency of boiler and furnace .... "	67.85	68.43	69.65	69.05	69 65	69.6
Efficiency of boiler, furnace, and economizer .... "	74.61	75.06	76.69	75.14	76.44	76.41
Loss of heat due to radiation, absorbtion, etc., per pound of actual coal .... "	13.9	11.4	10.7	12.2	11.0	11.8

excepting No. 134, grouped into 12-hour runs and one 10-hour run. By comparing these results with those of the 6-hour trials, the difference is quite marked in point of variation. It will also be seen that in every 6 hours' trial just following the cleaning period, the efficiency is high and the "unaccountable loss" low, while just the reverse is the case for those runs taking in the cleaning period. The curves in Fig. 253 show the increase in evaporation and efficiency and the decrease in the unaccounted loss as the trial progresses.

After the completion of the 76 hours' series, it was decided to cover the boiler walls with some insulating material, make two trials as nearly identical as possible, the only difference being with and without walls covered, and observe what effect such conditions had upon the "radiation and unaccounted loss" of the heat balance.

Therefore, magnesia blocks 6 inches by 36 inches by 1½ inches were used, covering the side walls to within two feet of the floor and also the top of the furnace, the blocks being held to the boiler walls by wooden strips. The block joints were made with magnesia mortar, and all other openings and crevices filled with the same material, so as to allow the cold air practically no chance to get to the walls.

21. The boiler having been again thoroughly cleaned, the two trials were conducted in the usual way, using Fairmont coal furnished by the Fairmont Coal Co., of Fairmont, West Virginia. The magnesia blocking was removed immediately at the end of the first run. During these trials, and also in others, the thermo-electric pyrometer was used for taking temperatures at the points A, B and C, Figs. 247 and 248. The temperatures thus obtained will

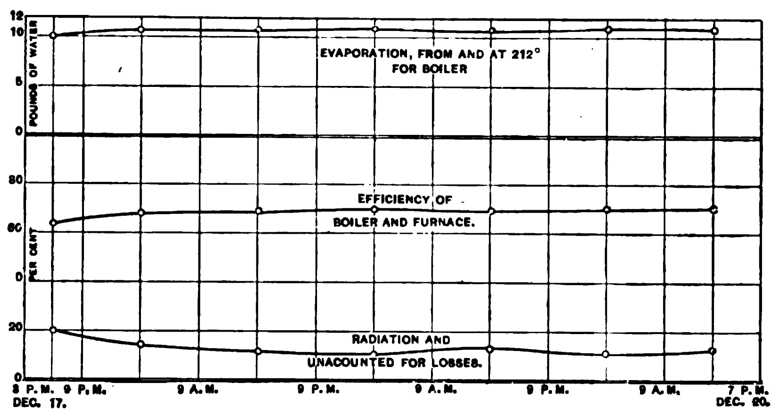


FIG. 253.

only be given at this time for trials Nos. 165, 166 and 167, as it is the intention of the writer, after collecting much more data in this particular direction, to make such the subject matter of a subsequent paper.

22. From the results obtained on trials Nos. 165 and 166, from a table which is not presented by reason of its elaborate character,* since it was very desirable to make the running conditions as nearly identical as possible, it was observed how near such was accomplished by comparing the draft, coal per square foot grate per hour, per cent. of refuse and combustible matter in same, power developed, thermo-electrical pyrometer readings and heat balance, the last showing why the higher evaporation was obtained on the latter run. The difference in the "radiation and unaccounted for loss" is so slight, although in favor of the covering, that one can hardly say that such a small difference was due to that agency. It is possible, however, that such a loss might have

* This table numbered as Table 6 in the series can be obtained as a blue-print from the original tracing by those interested on application to the Author.

shown up greater if the trials were of longer duration, and yet that hardly seems likely when the wall temperature curves, Figs. 254 and 255, are compared. Nevertheless there must be a saving in heat on account of the covering, although the tests here reported do not show it, and it may be possible that such saving can not be shown up by this method.

Thermo-electric pyrometer readings for trial No. 165. Degrees Fahr. Duration of trial, 10 hours—7.30 A.M. to 5.30 P.M.

TIME.	A	B	C		
10.30 A.M.	2,550	1,050	770	Sliced	8.45 A.M.
10.32 "	2,400	....	...	"	11.00 "
11.30 "	2,560	1,200	830	"	12.30 P.M.
2.05 P.M.	2,510	1,090	810	"	2.00 "
4.30 "	2,570	1,160	830	Cleaned	3.40 "
Average ...	2,518	1,125	810		

Thermo-electric pyrometer readings for trial No. 166. Degrees Fahr. Duration of trial, 10 hours—7.30 A.M. to 5.30 P.M.

TIME.	A	B	C		
8.00 A.M.	2,510	1,140	820	Sliced	8.45 A.M.
9.00 "	2,550	1,000	780	....	
10.00 "	2,575	1,130	840	....	
11.00 "	2,550	1,140	760	Sliced	11.00 A.M.
12.00 "	2,470	1,140	820	"	12.15 P.M.
1.00 P.M.	2,470	1,100	780	"	1.20 "
2.00 "	2,600	1,140	860	"	2.30 "
3.00 "	2,490	1,100	760	Cleaned	3.40 "
4.00 "	2,470	1,130	880	....	
5.00 "	2,460	1,020	780	....	
Average ...	2,514	1,104	808		

23. Trials No. 108 and No. 114 were conducted with a view to bring out some points on which the writer wished to satisfy himself—that is, with this particular equipment—to learn the possible error due to starting trials by the standard method. With trial No. 108 (Table 7) the boiler was run continuously for something over 30 hours previous, fires were drawn, furnace and ash pit doors closed tight and dampers open just enough to be able to detect some draft by the differential draft gauge. The valve in the main steam line above the boiler was then closed and the time noted for pressure on boiler to raise one pound. The new fire was then kindled and the boiler brought immediately to working

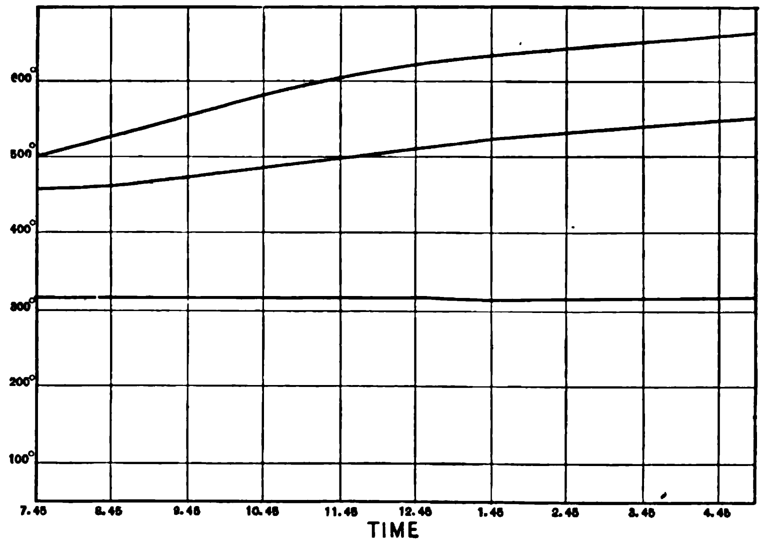


Fig. 254.

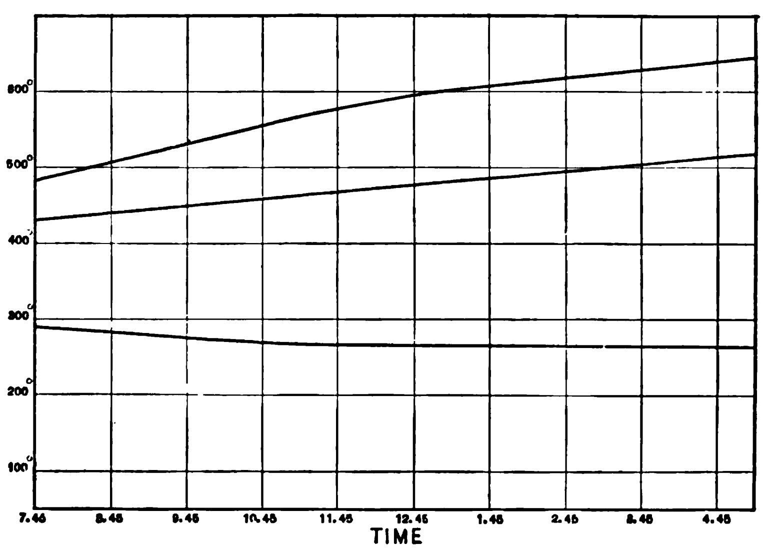


Fig. 255.

conditions. The trial lasted 10 hours, at the end of which the same process was gone through as at the beginning. It was found that after 4 hours and 40 minutes, during which time the steam pressure was maintained the same as throughout the run and the necessary feed water supplied the boiler to keep constant height of water in the drum, the boiler was steaming at the same rate as at the beginning of the trial. The feed-water so supplied for that time was 1,620 pounds, which would increase the evaporations under actual conditions from 7.336 pounds to 7.75 pounds, or 4.95 per cent.

24. With trial No. 114 (Table 7) both methods of starting were employed, the trial by the standard method extending from 6.15 a.m. to 4.25 p.m., while by the alternated the period was from 7.30 a.m. to 3.30 p.m. As will be seen by the results given, the evaporation under actual conditions by the alternate method was 8.518 pounds of water, while that by the standard—the total water supplied being 29,050 pounds, and coal (plus wood equivalent), 3,564 pounds—was 8.15 pounds of water per pound of coal under actual conditions, or a difference between the two methods of 4.33 per cent. At the end of this trial also the same method was gone through as on trial No. 108. When the equality of steaming was reached at the end of 5 hours, the boiler had during that time taken 1,710 pounds water, making a total from the time of lighting the fire of 30,760 pounds, thereby giving an actual evaporation of 8.63 pounds water per pound of coal, which compares closely with that obtained by the alternate method, of 8.518 pounds, an excess of the former over the latter of only 1.31 per cent. From the results obtained by these two trials, the writer believes it safe to conclude that for any external fired boiler with brick setting and oven, or fire brick arch furnace, the errors introduced by using the standard method for starting a trial will amount to about 5 per cent., that amount, of course, decreasing as the length of the trial increases.

Trials Nos. 108, 160, 162 and 163 (Tables 7 and 8) were all made with Hackers Run coal, furnished by the Southern Coal and Transportation Co., Berrysburg, West Virginia.

Trial No. 108 was with medium low draft, giving a rate of combustion of 21.13 pounds of coal per square foot of grate per hour.

TABLE 7.

Kind of fuel	Hackers Run	George's Creek
State of weather	Clear	Clear
Date of trials 1901	March 23	May 13
Duration of trials	10 hours	8 hours
Number of trials	108	114
AVERAGE PRESSURES.		
Steam pressure by gage lbs. per sq. in.	97.8	111.3
Atmospheric pressure by barometer ins. mer.	29.24	29.4
Absolute steam pressure lbs. per sq. in.	112.2	125.8
Force of draft leaving boiler ins. water	.235	.156
AVERAGE TEMPERATURES.		
External air deg. Fahr.	55	66
Fire room "	77.7	82
Feed water entering boiler "	56	60.7
Air entering ash pit "	77.7	82
Escaping gases from boiler "	485	520
FUEL.		
Size and condition	Lump	Run of Mine
Method of firing	Cross	Spreading
Total weight of coal fired lbs.	4,226	3,539
Weight of coal fired during test "	4,226	2,845
Percentage of moisture in coal by analysis	.85	.88
Weight of dry coal consumed during test lbs.	4,190	2,820
Total weight of ash and refuse "	516	230
Combustible consumed during test, computed from analysis of refuse "	3,628	2,583
Weight of clinker from total coal "	....	38
Percentage of ash and refuse to coal per cent.	12.22	6.5
" clinker to coal "	....	1.07
PROXIMATE ANALYSIS OF COAL.		
Fixed carbon per cent.	53.55	......
Volatile matter "	34.85	......
Moisture "	.85	.88
Ash "	10.75	7.93
ULTIMATE ANALYSIS OF COAL.		
Carbon per cent.	72.05	81.79
Hydrogen "	5.00	4.28
Oxygen "	7.40	4.60
Nitrogen "	1.00	.56
Sulphur "	3.80	.84
Ash "	10.75	7.93

TABLE 7.—*Continued.*

ANALYSIS OF ASH AND REFUSE.

Ash	per cent.	80.70	90.27
Volatile combustible	"	19.30	9.73

FUEL PER HOUR.

Coal consumed per hour	lbs.	422.6	355
Combustible consumed per hour	"	362.8	323
Coal per square foot of grate per hour	"	21.13	17.7
Combustible per square foot of heating surface per hour	"	.339	.30

CALORIFIC VALUE OF FUEL.

Calorific value per pound actual coal by Mahler Calorimeter	B. T. U.	13,642	14,168
Calorific value per pound dry coal	"	13,764	14,293
" " " combustible	"	15,438	15,415

QUALITY OF STEAM.

Percentage of moisture in steam	per cent.	1.3	1.
Quality of steam (dry steam = unity)	"	.987	.99
" Correction	"	.9904	.9925

WATER.

Total weight of water fed to boiler	lbs.	31,132	24,236
Equivalent weight of water actually evaporated into dry steam	lbs.	29,228	24,053
Factor of evaporation		1.2017	1.198
Equivalent weight of water evaporated into dry steam from and at 212 degrees	lbs.	35,123	28,816

WATER PER HOUR.

Equivalent evaporation per hour from and at 212 degrees	lbs.	3,512	3,602
Equivalent evaporation per hour from and at 212 degrees per sq. ft. heating surface	"	3.28	3.46

HORSE-POWER.

Builders rated horse-power	107	107
Horse-power developed	101.8	104.2

TABLE 7.—*Continued.*

ECONOMIC RESULTS.

r apparently evaporated under actual conditions ɛer pound of coal as fired	lbs.	7.366	8.518
ɾalent evaporation from and at 212 degrees per ɔound coal	"	8.310	10.13
ɾalent evaporation from and at 212 degrees per ɔound of dry coal	"	8.382	10.22
ɾalent evaporation from and at 212 degrees per ɔound of combustible	"	9.667	11.16

EFFICIENCIES.

ɛncy of boiler and grate	per cent.	58.81	69.03
"	"	60.47	69.9

ANALYSIS OF FLUE GASES.

		Vol.	Wt.	Vol.	Wt.
arbon dioxide	per cent.	7.9	11.71	10.12	14.85
xygen	"	10.	10.79	9.12	9.73
arbon monoxide	"	.2	.19	.04	.04
itrogen	"	81.9	77.31	80.72	75.38
ntage of air excess	"	86.9		75.6	
ls of air used ber pound of coal		17.7		18.6	

HEAT BALANCE.

	B.T.U.	%	B.T.U.	%
ɛr pound of coal due to products of combustion	1,049	7.69	1,236	8.75
" " " air excess	796	5.84	831	5.86
" " " latent heat	464	3.37	396	2.79
" " " unburned coal	393	2.89	132	.93
" " " CO	181	1.33	34	.23
" " " radiation, etc.	2,738	20.07	1,758	12.41
ısed in evaporation	8,026	58.81	9,791	69.03
	13,647	100.	14,158	100.

ı. Trial No. 160 was with stronger draft, giving a rate of comon of 29.07 pounds of coal, but in comparing this trial with 108, it should be born in mind that the former was started by tandard method, while with the latter the alternate method was oyed. Taking this into account, the true evaporation from at 212 degrees Fahr. for trial No. 108 would be practically pounds of water per pound of coal, which value should be used in comparing with trial No. 160. Making this correction in the heat balance, the "radiation and unaccounted for loss" would be reduced to 2,323 British thermal units, or 17.1 per cent., so that in comparing the two trials by the heat balance, the reduced evaporation for trial No. 160 is due to higher loss in products of combustion, in excess air and formation of CO.

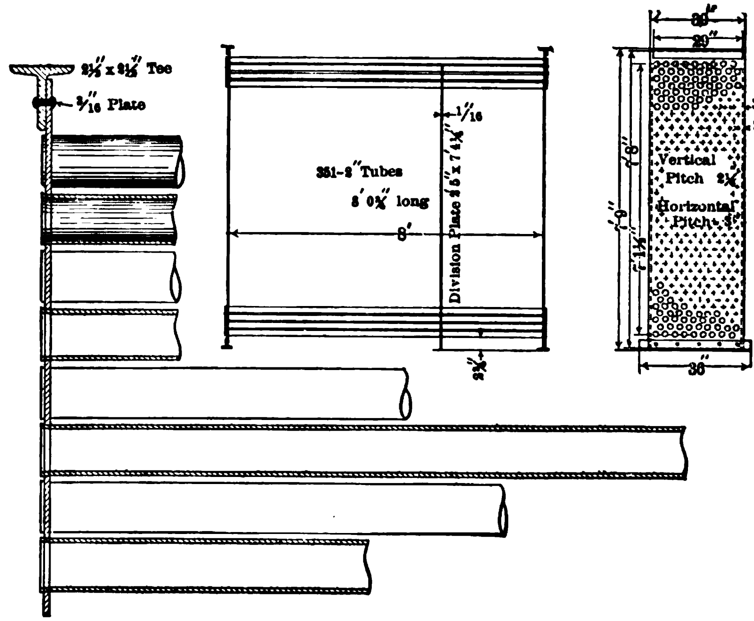


FIG. 256.

Trials Nos. 162 and 163 are cases where, for the former, boiler and air heater were used, and forced draft with boiler alone for the latter. In all four trials with Hacker Run coal, the case where the air heater was used gave the highest efficiency, but by a very small amount.

Trial No. 167 is a case where the grate area is reduced to 15 square feet, giving a ratio of grate to heating surface of 1 to 71. Using Fairmont coal with an average forced draft of + .313 inches in the ash pit and — .228 inches at end of boiler, giving at a net draft of .541 inches under which 36 pounds of coal were burned per square foot of grate per hour, the boiler generating 31 per cent. more steam than its rated capacity.

TABLE 8.

Kind of fuel : Hackers Run.

f weather....	Clear	Overcast	Overcast
f trials. 1902	Feb. 12	March 4	March 5
on of trials.............. ....hours	9	9	9
er of trial..	160	162	163

AVERAGE PRESSURES.

n pressure by gage.........lbs. per sq. in.	.98	95.9	96.1
spheric pressure by barometer. .ins. mer.	29.40	29.28	29.3
lute steam pressure ....lbs. per sq. in.	112.5	110.26	110.7
of draft leaving boiler........ins. water	.552	.464	.209
" " air heater ... "	....	.538	....
" or blast in ash pit .... "	— .02	+ .186	+ .440

AVERAGE TEMPERATURES.

rnal air.......................deg. Fahr.	22.7	34	34
room....................... "	57.9	68	53.6
water entering boiler.......... "	53.2	53.6	52
ntering ash pit............... "	57.9	242	53.6
ping gases from boiler......... "	556	572	702
" " " air heater .... "	....	397	....

FUEL.

and condition	Lump	Lump	Lump
hod of firing	Cross	Cross	Cross
kness of fire ....inches,	9	7½	7
l weight of coal fired ....lbs.	5,923	5,353	6,972
ght of coal fired during test............ "	5,233	4,668	6,284
entage of moisture in coal by analysis	.85	.85	.85
ght of dry coal consumed during test...lbs.	5,188	4,628	6,232
al weight of ash and refuse............ "	621	553	669
bustible consumed during test, computed from analysis of refuse......... "	4,553	3,971	5,438
ght of clinker from total coal .... "	166	162	201
centage of ash and refuse to coal .per cent.	10.48	10.33	9.6
" clinker to coal........ "	2.8	3.02	3.01

PROXIMATE ANALYSIS OF COAL.

ed carbon ....per cent.	53.55	53.55	53.55
atile matter .... "	34.85	34.85	34.85
isture......................... "	.85	.85	.85
.... "	10.75	10.75	10.75

TABLE 8.—*Continued.*

Ultimate Analysis of Coal.

Carbon	per cent.	72.05	72.05	72.05
Hydrogen	"	5.00	5.00	5.00
Oxygen	"	7.40	7.40	7.40
Nitrogen	"	1.00	1.00	1.00
Sulphur	"	3.80	3.80	3.80
Ash	"	10.75	10.75	10.75

Analysis of Ash and Refuse.

Ash	per cent.	84.20	75.75	84.30
Volatile combustible	"	15.8	24.25	15.70

Fuel per Hour.

Coal consumed per hour	lbs.	581.4	518.7	698.2
Combustible consumed per hour	"	505.1	441.2	604.2
Coal per square foot of grate per hour	"	29.07	25.9	34.91
Combustible per square foot of heating surface per hour	"	.472	.412	.564

Calorific Value of Fuel.

Calorific value per pound actual coal by Mahler Calorimeter	B. T. U.	13,647	13,647	13,647
Calorific value per pound dry coal	"	13,764	13,764	13,764
" " " combustible.	"	15,438	15,438	15,438

Quatity of Steam.

Percentage of moisture in steam	per cent.	1.7	1.27	1.48
Quality of steam, (dry steam = unity)	"	.983	.9873	.9851
" correction	"	.9871	.9906	.989

Water.

Total weight of water fed to boiler	lbs.	36,568	34,741	45,704
Equivalent weight of water actually evaporated into dry steam	"	36,106	34,414	45,201
Factor of evaporation		1.203	1.2067	1.2054
Equivalent weight of water evaporated into dry steam from and at 212 degrees	lbs.	43,435	41,527	54,485

TABLE 8.—*Continued.*

Water per Hour.

ivalent evaporation per hour from and at 212 degrees....................lbs.	4,826	4,614	6,054
ivalent evaporation per hour from and at 212 degrees per sq. ft. heating surface "	4.51	4.31	5.665

Horse-power.

ders rated horse-power	107	107	107
se-power developed	140	133.7	175.7

Economic Resultes.

er apparently evaporated under actual conditions per pound of coal as fired...lbs.	6.989	7.443	7.272
ivalent evaporation from and at 212 degrees per pound coal .... "	8.30	8.896	8.668
ivalent evaporation from and at 212 degrees per pound dry coal .... "	8.372	8.975	8.742
ivalent evaporation from and at 212 degrees per pound of combustible .... "	9.552	10.46	10.02

Efficiencies.

iency of boiler and grate ....per cent.	58.74	62.97	61.33
" " .... "	59.74	64.81	62.66

Analysis of Flue Gases.

	Vol.	Wt.	Vol.	Wt.	Vol.	Wt.
Carbon dioxide ....per cent.	8.02	11.89	9.41	13.87	11.38	16.64
Oxygen .... "	10.38	11.19	9.06	9.71	6.63	7.08
Carbon monoxide .... "	.60	.56	.32	.30	.48	.45
Nitrogen .... "	81.00	76.36	81.22	76.12	81.48	75.83
ntage of air excess .... "	95.4		73.9		45.3	
ds of air used per pound of coal .	18.6		16.2		13.7	

Heat Balance.

	B.T.U.	%	B.T.U.	%	B.T.U.	%
er lb. of coal due to products combust'n	1,261	9.24	838	6.15	1,668	12.23
" " " air excess	1,048	7.68	540	3.97	657	4.82
" " " latent heat	466	3.42	459	3.36	466	3.42
" " " unburned coal....	307	2.25	526	3.85	306	2.24
" " " CO.............	525	3.85	238	1.74	302	2.22
" " " radiation, etc.	2,024	14.82	2,454	17.98	1,876	13.74
used in evaporation	8,016	58.74	8,592	62.95	8,372	61 33
heat supplied	13,617	100.	13,647	100.	13,647	100.

Thermo-electric pyrometer readings for trial No. 167. Duration of trial, 9 hours—8 a.m. to 5 p.m.

TIME.	A	B	C	REMARKS.
8.45 A.M.	2,810	1,440	880	....
9.45 "	2,400	1,190	830	....
10.45 "	2,600	1,250	940	....
11.45 "	2,750	1,270	940	Sliced 11.30 A.M.
12.45 P.M.	2,520	1,270	950	....
1.45 "	2,460	1,190	880	....
2.45 "	2,610	1,320	930	....
3.45 "	2,600	1,250	940	Cleaned 3.00 P.M.
Average ..	2,594	1,272	911	

26. Comparing these temperature readings with those of trials Nos. 165 and 166, it will be observed that the forced draft was productive of higher furnace temperatures and would therefore have caused a higher efficiency of boiler if the grate area had been so reduced that the flue temperature had been practically the same, since the heat balance of the trials in comparison shows the great difference to be mostly in the loss due to products of combustion and air excess.

One of the many interesting points shown by the trials here given is the comparatively high rate of combustion produced with this type of furnace with what by many would be considered a very low draft. Trials on Ohio coals with this experiment boiler have given a rate of combustion of 26 pounds per square foot of grate per hour with .19 inch draft, while another trial with the same class of coal gave a rate of 41 pounds with a draft of .56 inch. In the first case the boiler ran 11 per cent. above its rating and in the second 75 per cent.

Another point is the fact that the " unaccounted for loss " per pound of actual coal does not go below 10.7 per cent.—that obtained for trials Nos. 139 and 140. With one exception that is the lowest " unaccountable loss " obtained with this boiler, on which up to the present time sixty-six heat balance trials have been conducted. In fact, out of about one hundred and fifty trials on stationary boilers conducted by the writer, for which there are complete heat balances based upon the calorific value of the coal by the Mahler calorimeter (determinations made by Professor N. W. Lord, or under his direction), there has been only one case where the " unaccountable loss " has gone below 7 per cent,, and that was the case of a trial on a battery of four boilers.

DISCUSSION.

Mr. A. Bement.—It will be interesting to make a comparison tween the efficiency of an ordinary boiler with an economizer, d a very efficient boiler without an economizer. For this I ve taken the trial in table 2, No. 104 *BE*, for comparison with e performance of an unusually efficient boiler described as fol- vs: It is a large Heine boiler, 17 tubes high, as installed by the iker; the travel of the gases among the tubes was from the ck lower to the front upper corner; on this diagonal line the

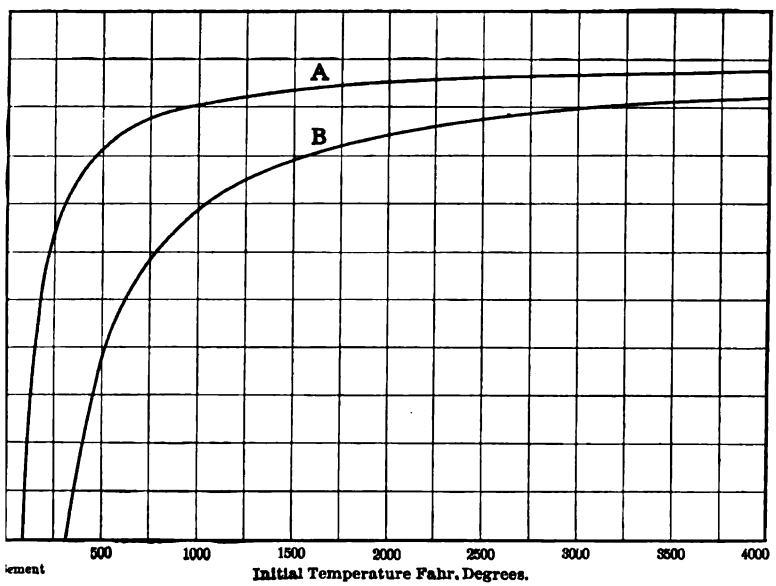


FIG. 257.

t gases travelled a distance of about 13.3 feet in contact with tube surface, or in other words had what is known as the Ieine pass," as far as I am aware, common to all boilers in- lled by the maker of this boiler. Its performance when evap- iting 4.04 pounds of water per square foot of heating surface hour, with a condition of combustion represented by 10.7 cent. CO_2 and no CO, resulted in the gases leaving the boiler 278 degrees Fahr. above steam temperature. To increase the ciency of a number of boilers similar to this one described, . W. L. Abbott and myself devised an arrangement of baffles, ich caused the gases to travel a distance of about 36 feet in contact with the tube surface. This was accomplished by the insertion of two additional horizontal baffles, which cause the gases to flow forward among a portion of the tubes at the bottom of the boiler, then back among a portion of the middle tubes, thence forward again among the tubes at the top. The result of this improvement was that the gases left at 92 degrees Fahr. above steam temperature when evaporating 4.17 pounds of water per square foot of heating surface per hour, with a condition of combustion represented by 10.3 per cent. CO_2 and no CO. It is my understanding that this is the first application of such method of baffling applied to a Heine boiler; the makers, however, state that they have considered such scheme in connection with their boilers.

The comparison of efficiency is based on the relative cooling effect produced on the hot gases by boiler and economizer in one case, and by the boiler only in the other. Radiation would be responsible for a very slight cooling effect, not enough, however, to be considered, and may be assumed to be the same in each case, as each apparatus is well set. The efficiency, or cooling effect may be oppressed by

$$E = \frac{R\,1 - R\,2}{R\,1},$$

R 1 being the initial rise in temperature, or temperature in the furnace, and R 2 the final rise, or temperature of gases leaving above the temperature of the cooling medium the water in the boilers and enconomizer.

The performance of the two apparatus is as follows:

	B. & W. and Economizer.	Improved boiler.
Pounds of water evaporated per square foot of heating surface per hour	3.8	4.17
Temperature of cooling medium, average	272	377
" " " " water entering economizer	49.9	
Final rise above average temperature of cooling medium	88	92
Final rise above water entering economizer	310	
CO_2	10.82	10.3
CO	0.23	0.0
Coal	West Va.	Illinois.

Assuming that the final rise in temperature would be constant throughout the full range of the initial, the efficiency or cooling effect of the improved boiler is illustrated by curve A of the diagram (Fig. 257). With the combined boiler and economizer if the al rise is taken as 310 degrees, the efficiency is illustrated by ·ve *B*; this, however, is not correct, because 49.9 is not the ɜrage temperature of the cooling medium, it is the tempera- ·e in the last end of the economizer only. Basing the final ɜ on the average temperature of the cooling medium gives 88, y 4 degrees below that of the improved boiler, the efficiency boiler and enconomizer being so near that of the improved ler alone as to fall almost on the same line. With the B. & there was some carbon monoxide which would influence the tial temperature, but on the other hand the coal used with the proved boiler contained about 11 per cent. of moisture, there- e it may be assumed that the initial temperature was the same ach of the tests. With the improved boiler, however, the work formed per square foot was about 9 per cent. greater, and if the nbined boiler and economizer had worked at the same capacity, final rise in temperature would have been at least as high as t of the improved boiler. From the foregoing it appears that combination of this particular boiler and its economizer has greater efficiency than that of the improved boiler alone.

Regarding the depreciation of the heating surface of a boiler the immediate vicinity of the fire, the explanation offered is in my opinion the true one, and it does not appear that there ny evidence to support the assumption that such effect is pro- ed by the process of combustion. In my opinion this trouble caused by such portion of the heating surface being called n to transfer more heat than is absorbed, which results in rheating of the metal. Some examples and their remedy y be mentioned. A return tubular boiler, set just back of furnace so that the head of the boiler and tubes only were d as heating surface, gave great trouble from the tubes leak- . The remedy consisted in locating a drum below the grate face and a short distance forward of the end of the boiler; r the furnace and just above the lower one another drum was ced; these were connected by a number of straight vertical es. The lower drum was connected to the boiler below the ter-line, and the upper one to the boiler above the water. is resulted in sufficient reduction of the temperature of the ses to relieve the boiler-head of a sufficient amount of work stop the trouble. Another similar case was remedied by cov- ng the boiler-head with a refractory non-conducting material, t leaving openings opposite the tubes. In each of these cases there was less surface in the boiler-head than there was in the grate, and it was this limited area which received the full force of the high temperature, because the hot gas did not reach the tube surface until after leaving the head. With some styles of horizontal water-tube boilers the bottom half of the lower row of tubes is exposed directly to the furnace and those above cut off by a tile baffle. This lower row gives considerable trouble from overheating, especially when the boiler is worked at a fair capacity. When it is considered that as much as 35 to 40 pounds of water may be evaporated per hour from a square foot of surface so located, it is readily apparent that it will not take many square feet of surface to evaporate more water than can find entrance to the tube. With such cases as this, if the heat transfer to a portion of the surface is cut off, the trouble will be remedied; it may be accomplished by building an arch over the fire, so that it extends some distance under the boiler, or by encircling the lower tubes for a portion of their length with a refractory non-conducting tile. This results in reducing the evaporating capacity of a tube, and consequently its water supply may then be sufficient.

The composition of the ash and refuse is given as ash and volatile combustible; I do not understand what is meant by the latter. Dry refuse, as it would accumulate in the ash pit, could contain ash, coke and coal, and its proximate analysis would show ash, fixed carbon and volatile matter, the latter being mostly combustible.

The unaccounted for loss of the heat balance is a considerable item, and it would appear that if it is desirable to maintain a special steam-generating apparatus for the purpose of experiment, that it would be profitable to study the loss owing to escaping hydrocarbons.

Mr. R. S. Hale.—Professor Hitchcock's paper is an admirable contribution to the literature of the subject, and is a refreshing contrast to the mass of boiler trials, which are valueless because without complete data. It is a pity that some of the data that have filled previous volumes of the proceedings could not have been omitted so as to furnish room for the really valuable data which have been omitted from the printed matter of the Professor's paper on account of lack of space. I should like to discuss the paper *in extenso*, but will merely touch on one point which I fear may be misleading.

[he statement in paragraph 24 to the effect that the error of the ndard method is 5 per cent., does not say whether this is the ›bable or maximum error, while on page 37 it is implied that s 5 per cent. is rather in the nature of a correction than a e error.

The results of trials 134 to 145, which Professor Hitchcock ; kindly sent me, show very nicely the probable error of the ernate method. Omitting trials 134 and 145, which were tly by the standard method, we have ten trials. The evap-tion, of course, varies slightly with the air supply, etc., but variations in the per cent. unaccounted for show better than thing else the errors, and we find that the average variation m the mean of the per cent. unaccounted for in these ten ils was 2.1 per cent., the maximum variation was 3.4 per it., and the probable error of each test 2 per cent., and the ›bable error of the mean $\frac{6}{10}$ per cent. These probable errors computed from the actual variations, not from the least iare method, but the difference of the least square method uld be negligible.

These percentages are in per cent. of the heat of the coal. In cent. of the evaporation the probable error of each six-hour t would be roughly 3 per cent., and the probable error of the an of the ten tests 1 per cent.

These figures are based on the assumption that the true "un-ounted for" loss was constant. It may have been that the idition of the fire in respect to cleaning changed the "un-ounted for" loss, rather than caused an error in the estima-n of the weight of the net dry coal on the grate. I will refer this point later.

These figures show the probable error of the alternate method. ial 134 and 145 were each partly by the standard method. ial 134 began with cold boiler-walls, hence very naturally ows a high "unaccounted for," and shows nothing about the uracy of the method. Trial 145, I understand, ended with t boiler-walls—*i.e.*, with walls in the same condition as when began. It gives exactly the same "unaccounted for" as the an of all the trials, hence, so far as it goes, shows that the indard method is more accurate.

Trials 108 and 114 were, so far as I can judge, not correctly nducted. As I understand the standard method, the boiler ould be brought in all respects to working condition, then the test started by drawing fires, and the test ended by drawing fires when the boiler is in exactly the same condition as it was just before the test began. In trials 108 and 114, apparently the fires were started and steam gotten up, but the walls were not fully heated when the test began, while at the end of the test the walls were fully heated. It was there only to be expected that the standard method would, under these circumstances, show about 5 per cent. less evaporation than the alternate method, and this figure coincides fairly well with the difference between trials 134 and 135, where the walls were entirely cold at the start of 134. Trials 108 and 114 show to my mind that if the standard method is properly conducted it will give the same results as the alternate. I admit that the wording of the code is not sufficiently clear that the test must be ended in exactly the same way as it was begun, or rather it furnishes no criterion such as Professor Hitchcock's noting the time for the steam pressure to rise 1 pound. I would also note that it is possible to judge a standard method test so as to give the reverse result. If the boiler is worked to its full extent right up to the time of starting the test the walls will be very hot, while if at the end of the test the boiler is worked easily for a couple of hours the walls will cool down to some extent, and the result will be a slightly higher evaporation than the true one.

In all our work we must distinguish when we can between accidental errors of observation, such as in figuring the amount of coal on the grate, and errors of method such as comparing two tests where the air supply or other conditions are different. The assumption that the "unaccounted for" "loss" in the series of trials 134 to 145 was constant is not necessarily correct, as the variations might be due to something else than errors in the observation of the fire, but as the tests stand we have no safer way than to assume the "unaccounted for" "loss" constant.

A similar line of reasoning shows that in the alternate method there is no chance for any error of method, hence if enough tests are made the errors of observation (which are as apt to be plus as minus) cancel out, so that the average gives the correct result.

On the other hand the standard method, while less liable to errors of observation, is liable to a possible error due to change of conditions during the few minutes when the fire is being drawn.

Tests 108, 114, 134 and 145 in Professor Hitchcock's paper, wever, seem to show that if proper care is taken, as starting d finishing with the walls equally hot, the standard method ll give exactly the same result as the mean of a large number tests on the alternate method. Hence the error of method of e standard method is negligible. They would therefore fully nfirm the wisdom of the Boiler Code Committee in making awing fires the standard method, since there is no question but iat the probable and possible errors of observation are far eater with the alternate method. While Professor Hitchcock's ts show that he can conduct a six-hour test on the alternate ethod with a probable error of about 3 per cent. and a maxi-im variation from the mean of about 5 per cent. in ten tests, t with care to have the same conditions at the beginning and d of the tests the standard method would in six-hour tests ve been even more accurate. On the other hand, with care-ss testing, I think the maximum error of the standard method hardly more than 5, perhaps 10 per cent., while the alternate ethod in careless hands can easily give 100 per cent. error.

Mr. Allan Stirling.—At the first meeting of this Society in 80, I read a paper on boilers, and I am glad to take part in is discussion, as the boiler question is still of prime importance.

In paragraph 2 of this paper Mr. Hitchcock gives it as his inion that "every boiler furnace, stoker or hand fired, where tuminous coal is used, should have fire-brick arch extending the ngth of the grate-bars, not only for the purpose of obtaining gh furnace temperatures, but more complete combustion." In is opinion I heartily concur, and in all the numerous boilers hich have been built from my designs this feature is common, id it is a feature that has also been retained in the new boiler, ie Maxim, in which I am now interested. I am of the opinion, owever, that the cause of the heavy depreciation and failure of oiler-heating surfaces directly over a fire at a high rate of com-ustion, with the highly volatile coals, referred to by Mr. Hitch-ock as somewhat mysterious, can be found in every case. In ie Stirling boiler, for instance, the flame cuts very keenly at ie front tubes at the end of the arch, and failures of tubes at iis point are due to this cause, combined with defective circula-on. In the Maxim boiler this has been entirely corrected, and, lthough a number of Maxims have been subjected to very severe ervice for a number of years, there have been no failures of tubes.

The failures of tubes over the fire in the Babcock boilers are, in my opinion, due to imperfect circulation and an accumulation of scale.

In paragraph 3 of this paper the writer says that the floor space was limited. It would be difficult to select a boiler which would take up more floor space than a Babcock boiler with a Dutch oven in the front. The Maxim boiler takes only the floor space required for the grate, or, in this case, only the space taken up by the Dutch oven, and the space occupied by the Babcock boiler would be free for other purposes.

The boiler selected has also, in my opinion, the needless complication of two doors for each tube.

As to the radiation loss, I understand the writer of the paper puts it at from 10 to 20 per cent. In a recent number of *Engineering* I observe that Mr. Strohmeyer, the chief engineer of the Manchester Association, emphasizes this loss as one of the great objections to the water-tube boiler. In the Maxim boiler this loss has been entirely overcome, and, indeed, turned into a positive gain. I believe it was Mr. Hoadley—the father of the genial assistant to our very efficient Secretary—who first called my attention to the fact that the benefit of heated air supplied to the ash-pit was not only the additional heat units supplied, but it gave better combustion of the fuel, because the air supply was heated. Now the Maxim boiler has this peculiarity over any other practical boiler, that doors into the ash-pit can be put both at the front and at the back. Maxim boilers are set in battery without any space between; the usual space at each end and at the back is cut off from the fire-room by walls that are carried up to the top of the boiler-setting. The front ash-pit doors are always shut, and the back ash-pit doors are always open. The result is that the heated air from the boiler-setting is taken into the ash-pit, thus recovering the heat that would otherwise go out through the ventilator, and thereby increasing the economy by better combustion due to heated air supplied to the ash-pit, and all this without any air-heater or other apparatus for heating the air.

On the last page of the paper the statement is made that out of about 150 trials there has been only one case where the unaccountable loss has gone below 7 per cent., and that was the case of a trial on a battery of four boilers. This emphasizes one advantage of setting a number of boilers in battery. We set any number of Maxim boilers in one battery, because we do not quire to get at the sides of the boilers as everything is gotten from the fire-room.

If I still have a little time, Mr. President, I will make a sketch ı the blackboard showing how we set these boilers. Here is battery of boilers, say, four or six, as you choose, which are t close together without any space between. Here is the back all of the boiler-room—the end wall, the front wall. We set e boilers in that shape, and we build a wall here which would carried up to the top of the boiler-setting. That cuts this ace off entirely from the fire-room. You see, our furnace es right through from front to back. We have doors back re into the ash-pit. The front ash-pit doors are always shut, d the only way that the fire can get air is to draw it in from is space here. The fire-room is cool because the air circulates over the setting, and down in the space behind, and all the ated air is taken into the ash-pit which also improves the com-ustion because heated air is supplied to the coal.

Mr. A. A. Cary.—This paper describes a very interesting oiler plant, allowing, as it does, a considerable range of investi-ation concerning the generation of steam under a number of ifferent conditions.

I am pleased to note that some provision has been made in this lant to study the economy of fuel under different conditions of ırnace design; a most important subject which has hitherto ceived altogether too little attention in our technical schools.

There is no one form of furnace equally adapted to all kinds f coal, and the difference in design between a furnace adapted burn anthracite coal and one adapted to burn a bituminous oal carrying, say, 50 per cent. volatile matter, is very great ıdeed, while between such extremes a number of different con-tructions will be found necessary to secure proper fuel economy nd not only must furnace design be considered, but the matter f handling the fuel in the furnace is equally important.

I notice that this boiler equipment also affords the student an xcellent opportunity to learn by actual test the relative merits f various boiler attachments, such as are found in use in many team plants. Some of these, when properly applied, lead to conomies which make them desirable investments, while others rove most disappointing, and they sometimes are the source of onsiderable trouble and even loss.

I notice that this boiler plant is equipped with an apparatus for pre-heating the air supplied to the furnace, utilizing the hot waste gases to accomplish this heating.

Theoretically, this is a most attractive proposition, but practically, it seems that the theoretical requirements have been so insufficiently met that this form of apparatus might be classified as a questionable investment.

The pre-heater described in this paper contains 351 two-inch tubes, each 8 feet in length. It contains 1,330 square feet of heating surface, while the boiler to which it is attached contains 1,070 square feet of heating surface, making a ratio between the heating surface in the heater and that in the boiler of practically 1.243 to 1. Further, we see that the tests given show an average increase in the temperature of the air of 0.26 of a degree per each square foot of air-heater surface presented.

This corresponds very well to the results obtained in a series of tests conducted by United States naval engineers using a Babcock & Wilcox marine boiler equipped with an air-heating device. In these tests the increase of air temperature per square foot of air-heater surface was 0.2636 degree Fahr., but in this equipment the ratio of the boiler surface to the air-heater surface was as 1 is to 5.33.

In the well known boiler tests conducted by Mr. J. C. Hoadley in 1881 and 1882, and reported before the Society, he used an air-heating device containing a greater amount of heating surface than was contained in his boiler, the comparative ratio being as 1.6 is to 1, and with this extended surface he only succeeded in increasing his air temperature 0.132 degree Fahr. per square foot of air-heater surface.

Mr. Bennis, whose name is well known in England in connection with an automatic stoker, in order to demonstrate the fallacy of certain claims made by an "enthusiastic" inventor of an air-heating device, experimented with 50 feet of two-inch pipe which he heated red hot, and maintained this temperature while he forced air through it at the rate of 1,000 feet per minute. The increase in the temperature of this air under such extraordinary conditions was 0.75 degree Fahr. per square foot of air-heater surface.

In the Babcock & Wilcox boiler tests, just mentioned, a number of tests showed only one-half of 1 per cent. gain in efficiency, due to the use of the pre-heated air, while the maximum gain during all tests was 2½ per cent., which results are very discouraging when we are considering the adoption of air-heaters.

Recently there have been a number of devices for pre-heating air offered to the steam using public, whose inventors or manufacturers claim wonderful saving in coal consumption when their devices are used, but with the results I have given before us, it will certainly pay the prospective purchaser to make a very careful investigation of the device before making such an investment.

Mr. John McGeorge.—I would like to say a little on this subject of pre-heating air, as there seems to be some misunderstanding about it. It seems to me that there is no value or economy in pre-heating air unless you have waste heat. In open hearth furnaces we have considerable surplus heat from the process of combustion because we have to maintain such a high temperature, and that can be utilized in heating the air for combustion. But there is another side to the subject. If you attempt to burn gas from coal, or to burn coal to gas—either case will illustrate what I want to get at—you must maintain a certain temperature to enable that combustion to take place. In other words, there is the heat of combustion as well as the heat produced by combustion. In the old days when I was with a boiler insurance company we received many reports showing a furnace directly under the boiler, where the flame of combustion coming against the cold water was checked in combustion and so produced soot or smoke. Now, if you take the same combustion under an arch you get that combustion complete before it touches the cold surfaces. (And when I say cold surfaces, I mean comparatively cold surfaces.) Then you will have the full value of furnace combustion going to heat the water in the boiler. Here, it seems to me, is the value of pre-heating the air if you cannot use the reverberatory arch. Then you heat the air to begin with to supply the heat of combustion, and you get a better value of the products of combustion. But if you have a good arch so that the combustion is not checked until it is complete, then it seems to me that there is no value in pre-heating the air; I mean, no comparative value, simply as a matter of economy.

Mr. A. A. Cary.—As far as the actual value of heated air for use in our furnaces is concerned, there is no question concerning its value.

To illustrate this, let us suppose the temperature of the outside air to be 60 degrees Fahr., and that of the escaping gases 600 degrees Fahr. Further, let us suppose that double the theoretical amount of air, required for combustion, is supplied to our furnace. There will be required to raise this excess air from 60 degrees to 600 degrees, about 1,487 heat units, which is about 10 per cent. of the heat of combustion developed by burning one pound of carbon to carbon dioxide. The nearer the temperature of the air (supplied to the furnace) is to that of the escaping gases the less this loss will be.

The point I wished to call attention to in my discussion was, the excessive cost necessary for a device which would yield but poor returns, and the experience of J. C. Hoadley was, that his air-heater was extremely troublesome and expensive from a point of repairs.

The loss due to the introduction of cold air into the furnace is not measured alone by the quantity of heat required to raise its temperature to that of the escaping gases, but the colder the air the greater is its tendency to lower the furnace temperature below the critical temperature of ignition of the gases distilled from the coal (which would tend to cause further loss due to incomplete combustion).

When air is introduced above the firebed, theoretically (to avoid loss due to its temperature), it should not be less than 1,400 degrees Fahr. (the ignition temperature of Marsh gas).

Air at 600 degrees Fahr. introduced at this point would tend to check combustion and thereby cause a loss.

Mr. Wm. Kent.—The most remarkable showing about these tests are the figures shown in the last line of Table V, on page 30 of the paper, the loss of heat due to radiation, absorption, etc., per pound of actual coal. In the different tests the figures are: 13.9, 11.4, 10.7, 12.2, 11.0 and 11.8 per cent. On page 41 a loss of as much as 17.98 per cent. is noted. That is, with this boiler especially built for tests, with all the facilities at hand in the University for making analysis, losses running from 10 per cent. upwards have to be reported as unaccounted for. Certainly, there is something wrong and it should be searched for and found out. The radiation loss on an ordinary boiler is not over 2 per cent.; though it may be 4 or 5 per cent. for this particular construction on account of the large surface exposed. But the radiation ought to be reduced not over 2 to 3 per cent.

Concerning the statement in the paper (page 3) regarding an extended arch, extending the full length of the grate-bars, there is no doubt that the author is entirely right in the statement that "a fire-brick arch should extend the length of the grate-bars, for the purpose of obtaining high furnace temperatures and more complete combustion——" That is all right as far as it goes, but then he adds: "Since there are many cases in practice where there have been heavy depreciation of the boiler heating surfaces located directly over a fire of high rate of combustion with high volatile coals, and the failures could be attributed to no other cause." That part of it needs to be modified. If we allow the gases, while in a state of combustion, to touch the comparatively cold surface of the boiler they will be chilled and part of them will go off unburned. The statement that there are many cases where "there has been heavy depreciation of the heating surfaces directly over a fire of high combustion and with high volatile coals and the failures could be attributed to no other cause," is not strictly accurate. The failure must be attributed to some other causes than the impingement of the gases on the tube. Wherever there is a very high temperature, whether from radiation or combustion, impinging on the surface of a heating boiler, and that surface is scaled or greased on the other side, it is liable to burn out. If we have grease and scale on the inside of the tubes, we may have a burn-out with a very moderate temperature of fire, and with either volatile or non-volatile coals. The high temperature on the outside of the tube may be the cause of the deposition of scale, just over the grate. The failure should then be blamed on the scale and not on the temperature, because in order to have steam at all we must have a high temperature at some point.

If, however, on account of too small an inclination of the tubes or other cause, the water is driven off from the surface of the tubes, or a "steam-pocket" is formed, then the tube may be burned out, but if the tube is free from scale or grease, and is full of water, freely circulating, it is impossible to burn out a tube by any temperature produced by the combustion of gases. I have heard, however, of the burning of tubes when the bed of coal was so high that hot coal actually touched the tubes. It is possible that the transmission of heat from hot coal, in contact with the heating surface, is so much greater than from hot gas that steam is formed on the heating surface, driving away the water, and in that case the tube may be burned.

Anotner criticism I have to make on the paper is in regard to the method of starting the tests, described on page 13. I have gone on record before in opposition to a similar method of starting a test. (See *Transactions*, vol. xxi., page 99.)

The best way of starting and stopping a test is to follow strictly the directions given in the Boiler Test Committee's report, under the heading of the "Alternate Method" (*Transactions*, vol. xxi., page 42), taking the precaution to burn the fires very low before cleaning, so as to leave on the grate only enough hot coal to start the fresh fire.

It is interesting to note that the author finds that the "Standard Method" of starting and stopping a test leads to an error of about 5 per cent. against the boiler, as compared with the results obtained by the "Alternate Method." This confirms the observations of Mr. E. H. Peabody, recorded in the *Transactions*, vol. xxi., page 126.

The great range of efficiencies obtained in these tests is especially notable. As low as 58.74 per cent. was obtained with Haeker's run coal, the highest figure obtained with this coal being 62.97 per cent. With Pocahontas coal the boiler efficiencies run from 69.03 to 73.84 per cent. It is evident that the combustion of the volatile matter of the Haeker's run coal was far from perfect.

It is to be regretted that in addition to the continuous method of sampling the flue gases, individual samples at different times after firing were not taken. In some of my tests I have taken a sample each minute for five or six minutes after firing, and these showed some rather remarkable resúlts when the coal was high in volatile matter and moisture. Thus, the sample drawn during the first minute, after firing, would show no oxygen and as much as 7 per cent. carbon monoxide, while the sample drawn during the fifth minute would show 7 per cent. O and no CO. Immediately after firing the furnace was a gas-producer, and much of the volatile hydrocarbon must have passed off unburned, which would account for the low efficiencies obtained. The Hempel apparatus was used in these tests. It is generally considered better than the Orsat.

*Prof. E. A. Hitchcock.**—Replying to Mr. Hale's discussion I wish to say that although in making trials with the installation

* Author's Closure, under the Rules.

described, I never used the standard method in starting believing it unfair for boiler and coal, yet I wished to determine for this particular equipment what the probable error would be in starting by that method under the conditions prevailing in order to be able to show by actual results to those persons who might raise the question, the probable error involved.

I am under obligation to Mr. Hale for bringing out this point which, as he says, may be misleading, but such, however, will not be the case I believe after going more into detail as to the conditions. As stated, the boiler is usually fired continuously for about thirty-six hours previous to the trial. This firing is usually done by one of the regular fireman of the boiler room and as he has many other duties naturally he will not fire this boiler as hard and as uniformly as is done on the trial and also since he knows that the testing crowd will come on at about 6 A.M. and draw the fire, he allows it to get dirty and consequently the boiler walls have a chance to cool somewhat. Such were the conditions at the time of starting trials Nos. 108 and 114, consequently the difference shown in the rate of steaming at the beginning and end of the trial. Therefore, the 5 per cent. spoken of on page 34 is the probable maximum error for a similar equipment under similar conditions.

My experience with an oven hand-fired furnace burning semi or bituminous coals is that when the furnace is working under proper conditions, the arch is white hot and the heat radiated so intense that even the putting in of a fire is quite severe on the fireman—therefore, how under such conditions could he at the beginning and end of a trial stand it to pull fires? If a thoroughly heated condition of the furnace does not prevail, the trial will not be fair to the boiler nor especially to the coal, since with a green fire of bituminous coal large quantities of CO are liable to be formed, and in burning down at the end of the trial preparatory to drawing the fire as prescribed by the Code in the standard method, there is liable to be high excess of air.

Mr. Hale speaks of trial No. 145, Table V. being partly by the standard method and uses it to prove the accuracy of such. The facts of that case are these—by 8.45 A.M. the fire was all cleaned, the trial started at 9 A.M. with the furnace hot and a 7-inch fire, the trial ended at 7 P.M. with furnace hot and a 7-inch fire—therefore, I should say that the trial comes in the same class as all of that series except trial No. 134.

Referring to Mr. Kent's criticism of the method employed in starting the trials or "the running start," I wish to say that he has very good ground for such criticism, having thrashed over the subject to quite a degree himself. Although there have been certain rules laid down, yet possibly there may be conditions such as require a departure from such rules. Most of the trials conducted by the writer have been and are for the principal purpose of determining the value of the coal under different boilers and with different forms of furnaces. Now, it is important that the conditions maintained be such as nearest conform to those in practice, and the methods employed for conducting the trials be uniform for the several types of furnaces. It surely would not be well to start a trial by the standard method on most automatic stokers and neither would the alternate method be used, for there would be no reason whatever for carrying out the directions of the Code, "the fires are to be burned low and well cleaned." It is a case of "running start," pure and simple.

In the testing of coals one important item is the true percentage of refuse, therefore, no other coal can be present on the grates at the time of starting the fire of test coal, nor any refuse in the ash-pit, consequently a record of the coal is kept from the time of starting the fire. It certainly would not be fair to the coal if, after changing over and running long enough to get boiler and furnace in a thoroughly heated condition "the fires were burned low and well cleaned," for there would be nothing to clean; and then, again, sometimes the coal is so clean and free from clinkering qualities, and the ash of such a nature, as to nearly all work into the ash-pit, that there would be no reason whatever at the end of the trial to have the fire burned low and cleaned.

It might be suggested that the amount of coal to be tested be sufficient for warming up, necessitating no changing of coal at the beginning of the trial. That would be all right if the sample submitted was large enough, but generally it is not, and even so, and the coal was used up to the time of starting the trial by either the alternate or standard method, one might have such a bad case of clinker to clean from the grate-bars that there would be an excessive cooling down of the brick work.

For a boiler with brick setting, especially where the value of the coal is to be determined, I believe thoroughly in the running start, when properly and carefully conducted, for our years of experience have demonstrated its accuracy. This is well shown by Table V., page 30, in the evaporation from and at 212 degrees, and the several efficiencies in the four last trials after the boiler was thoroughly heated. Also, bearing on this point, I give the following results of two trials conducted on consecutive days with nearly the same kind of coal:

Duration of trials......hrs.	10	10
Coal fired during trials......lbs.	5198	5206
Calorific value of coal, Mahler Cal......B. T. U.	12150	11937
Equivalent evap. from and at 212° per lb. coal.....lbs.	8.039	7.889

Heat Balance.	Per Cent.	Per Cent.
Loss per lb. of coal due to products comb......	8.48	8.85
" " " excess air......	4.58	5.87
" " " latent heat......	4.16	4.17
" " " unburned coal......	1.48	1.34
" " " CO......	1.90	.84
Radiation and unaccounted for loss......	15.49	15.60
Heat used in evaporation......	63.91	63.83

The above results are so nearly parallel that I consider them exceptional, and yet it shows what can be done, and is done, by that method of starting trials, and it is highly improbable that closer results could have been obtained by either the alternate or standard methods. Of course it is well seen how, in careless hands, a large error may be introduced by the running start or alternate method, but it is to me quite inconceivable how, as Mr. Hale states, an error of 100 per cent. could be made. It certainly would be quite impossible on our equipment in a ten-hour trial. Even an error of 10 per cent. would mean extremely poor judgment of the fire by the party conducting the trial.

To illustrate the accuracy of the running start in comparison with the standard method on a boiler of quite a different type from that described in this paper, the following case is mentioned of a trial conducted by the writer some months ago. The boiler was of the internal fired type with no brick work, with the exception of some used to cut down the area of the grates. The trial was started by the standard method and then again one hour later in our usual way, the trial proper lasting ten hours from this time. The evaporation under actual conditions being 7.988 pounds for the standard method and 8.004 for the trial proper, differing by .2 of 1 per cent.

Professor Kent calls attention to the loss of heat per pound of coal due to radiation, absorption, etc., as shown by the trials and intimates surprise that such high losses should be reported as "unaccounted for" from a University where, as some seem to suppose, there is every facility, ample means and plenty of time for going to the bottom of everything mysterious. Most of those who are in University work know how far such is from the case, we only wish it was much nearer the truth.

The writer in reporting these trials expected that the losses referred to would attract attention and therefore would give some one an opportunity to investigate a point which has been under investigation by us when opportunity would permit, for years. Professor Kent is perfectly justified in saying there is something wrong, providing that he can show by some seventy trials conducted by himself on a boiler and furnace of this type and size where the calorific value of the coal is determined by the Mahler Calorimeter, that the results given do not correspond with those obtained by him.

We have found that this unaccounted loss is dependent upon many things—*i.e.*, the type of boiler, size of boiler, the kind of setting, the kind of furnace, the coal (one that clinkers badly causing difficult cleaning, giving high loss) and the intensity of driving. To illustrate some of these points, the average loss of some trials are given. Nineteen trials with semi-bituminous coal gave for an average 12.6 per cent. with B. & W. boiler, hand-fired furnace; 34 trials with bituminous coal gave for an average 14.7 per cent. with same boiler and furnace; 13 trials with bituminous coal on B. & W. boiler with Murphy furnace gave for the average 12.6 per cent.; 2 trials on the same boiler and furnace with semi-bituminous coal gave 10.75 per cent.; 2 trials on 2 B. & W. double-deck boilers set in one battery, 700 total horse-power with chain grate, gave on consecutive days' running a loss of 6.3 per cent. and 5.9 per cent., and 5 locomotive trials gave an average of 1.1 per cent., the unaccountable loss for all of these trials being determined in exactly the same way.

The results compare closely with that obtained on a trial of a 150 horse-power water-tube boiler with individual setting and American underfeed stoker conducted in the city of Columbus some time ago by a prominent engineer of the Pennsylvania Railroad. The coal used was Pocahontas and the unaccountable loss 11.6 per cent.

Now if the above determined values include other losses than those of radiation, the question as to how much is radiation only in my opinion is quite impossible to answer with any degree of accuracy, for I have yet to find a case where that loss has been determined, not by difference, but experimentally under actual running conditions for a boiler with brick setting.

The statement by the writer in regard to depreciation of heating surfaces located directly over the fire, is based on his own observation, but the statement probably should have been qualified to special rather than general cases. Say for example, the case of the automatic stoker with short coking arch, the lengthening of which to nearly the length of the grates eliminated the trouble. The condition of uncleaned surfaces did not exist, and although the trouble might be attributed to some of the causes spoken of in the discussion, yet, nevertheless, the fact exists that the introduction of the arch cured the difficulty.

In the analysis of the refuse, the term "volatile combustible" is simply an abbreviation of Prof. N. W. Lord's for "volatile and combustible."

No. 998.*

DRAWING OFFICE EQUIPMENT.

BY JOHN MCGEORGE, CLEVELAND, OHIO.
(Member of the Society.)

1. WHEN I first said "Yes" in reply to a request from some of my friends to write this paper, I had in mind a general paper on the complete equipment of a drawing office; but the Secretary asked for something terse and to the point, so I have boiled down the generalities and tried to bring out particularly the necessity of saving the manual and mental drudgery of the draftsman, and thereby getting the highest possible efficiency.

There are many prominent engineers, and some of the very best ones, too, who look upon drafting as merely a means to an end, and think that the end which they seek is so much more important than the means, that they often think of drafting as too trivial to give it their attention.

Suppose a rolling mill is to be designed. Much attention is paid to the design, but the mill is simply a means to an end. Suppose that rails are produced from this mill, these rails are simply a means to another end, and so on indefinitely.

2. We estimate that from forty-five to fifty million dollars is paid to draftsmen in salaries in this country in a single year, and we cannot understand why so little attention has been given generally toward an equipment which will enable the men commanding these aggregate salaries, not only to produce drawings in the cheapest way possible, but also in the best way possible.

In talking the other day with a chief engineer, having a large force of draftsmen, he stated that when he took hold of this particular business, the man who had been in charge was buying the cheapest kind of paper and the cheapest supplies which he could obtain throughout. He thereby cut their supply bill from

---

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

$60 a month to $30 a month, or made a net saving on this item of $360 a year. The salary item was $100,000 a year, and as the gentleman put the matter, in order to save $360 a year on the supply account, he was jeopardizing the $100,000 item, and probably losing from $10,000 to $15,000 on that item.

Then again some engineers will state that they have draftsmen who can accomplish more with a short stub of a pencil, a cheap tee-square, and some old rusty instruments, than other men can do with the very finest equipment. This is very true, but it does not follow by any means that the first man would not accomplish more with a better equipment. There is still a great necessity to insist upon the truism that the best men in the best surroundings, and with the best conveniences, do the best work.

We supply our stenographers with good typewriters and nice desks, and our clerks with the best equipment which we can provide for them. In the shops we are anxious to put in all the labor-saving machinery possible, but in the drafting-room, where salaries are very much higher and where any saving counts a great deal more, both directly and indirectly, it is very generally true that the equipment is cut down to an extent which we cannot understand. It certainly ought not to be so.

3. The first point to be considered in the equipment of an office is the question of light. Daylight is the best as well as the cheapest, but is not at all times obtainable. In large drafting-rooms this light is not usually sufficiently diffused. The windows should be as high and as near the ceiling as possible, so that the interior of the room may receive light. The man next to the window should only have control of the shades covering the lower half of the sash, and the shades, both upper and lower, should be translucent. There are only two methods of artificial lighting which have proved to be perfectly satisfactory. The one is where arc or Nernst lights are used and the light reflected from them against dead white ceilings and walls. This gives good general illumination, which, if properly done, will dispense with individual lights. An illustration is given of a drawing office lighted by this method, Fig. 258, and another showing the same office in daylight, Fig. 259. This gives a very good idea of how well the light is diffused.

4. The writer thinks that if the Nernst 3 or 6 glower lamps were provided with shades underneath, throwing the light to the ceiling, these shades made just translucent enough so as not

Fig. 258.

FIG. 259.

to be a dark spot in the room, the walls and ceilings painted a dead white, then we would have a perfect light, soft, agreeable and without shadow; in short, a light closely approaching daylight.

In this connection the chief engineer of a large corporation, with offices in different cities, said that this method with arc lamps had proved perfectly successful in one office, but that he did not believe that it would do at all in the Pittsburgh district on account of the smoke and dirt making the white a dirty gray.

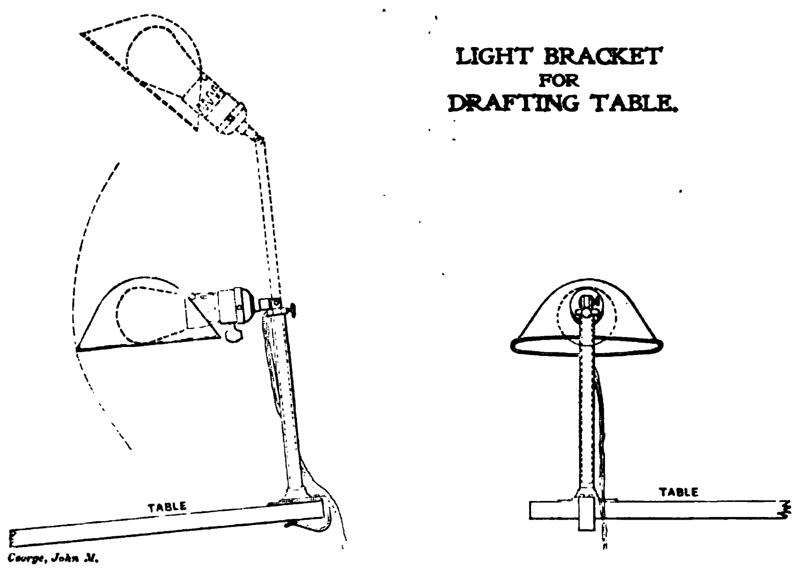


Fig. 260.

5. The other method which has given satisfaction is the individual lamp for each board. These should be made adjustable, and there are quite a number of methods in use for doing this. We show in Fig. 260 a sketch of a holder which we have found very satisfactory, and which is probably the simplest method.

Our temporary offices are now fitted with Nernst lamps, suspended from the ceiling at intervals of 6 to 8 feet apart, but when used in this way these lights cast shadows, and are not satisfactory.

6. The third important consideration is that of ventilation. No draftsman can do his best work without an abundant supply of fresh air. This is a matter which is receiving more and more

attention in the designing of schools and public buildings generally, and it is beginning to receive considerable attention in offices.

We change the air in our drafting-room as frequently as possible by means of an exhaust fan, but even when this is done we believe that from the standpoint of fresh air required, draftsmen should have at least double the space we have allotted to them. High ceilings are an aid in this matter as well as in the matter of light.

7. In the matter of desks the bulk of offices seem to be very neglectful of the fact that good conveniences tend to good work. A very large proportion are still fitted with nothing more than a pair of trestles, or a flat-top table, and a flat board with a tee-square.

In Vol. VI. of our proceedings Mr. Theodore Bergner described his parallel ruler, which was a step in advance, and on this has been founded a number of designs for boards, some of which have taken the incline position.

We (the Wellman-Seaver-Morgan Company) have been using a large number of Svenson boards, which have a frame carrying a parallel ruler on the Bergner principle, and in which frame can be placed a loose board, thus enabling a number of different drawings to be worked on without disturbing the paper on the board. The Svenson board can be placed at 60 degrees, 45 degrees, or flat (the ruler being balanced), and this to anyone troubled with bilious headaches is a great blessing. This board was supplied with a convenient desk below, and we also provided a chest of drawers to the left of the draftsman, the top of which served as a reference table, and the drawers provided ample room for reference drawings. In fact, we might say, too ample, as we had provided too many drawers, and whenever drawings were lost it required a great deal of work to find them.

8. While sufficient room should be given to each man for reference drawings and for partially completed drawings, it is undoubtedly a mistake to give more than enough drawers for this purpose, and in our new office we shall give each man two drawers for drawings, together with a good drawer for his tools and another for books and notes.

We found several objections to the use of vertical boards for average size drawings, and later we designed a table which could be adjusted in height and slope and used it in connection with

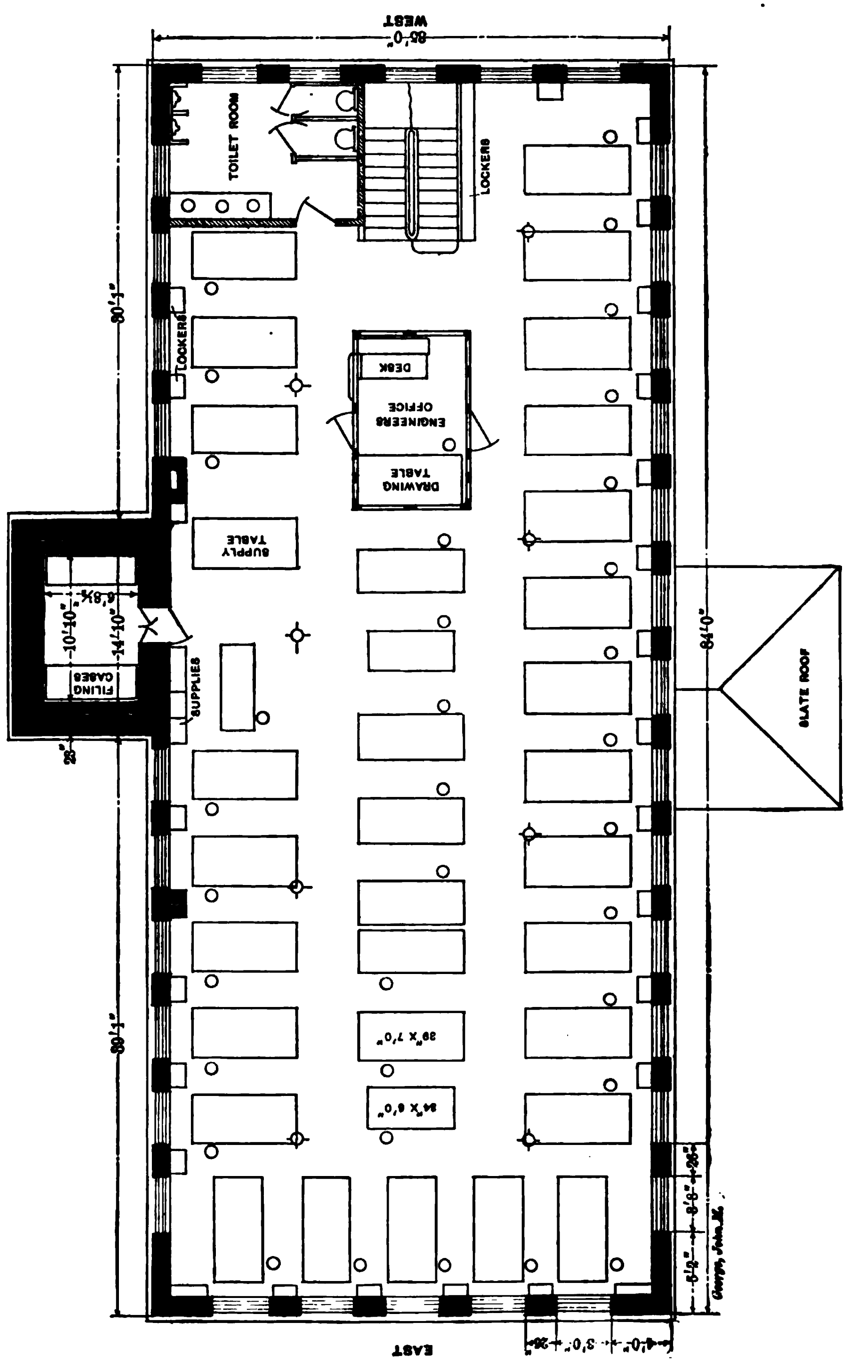

WEST
85'0"
TOILET ROOM
LOCKERS
LOCKERS
DESK
ENGINEERS OFFICE
DRAWING TABLE
SUPPLY TABLE
FILING CASES
SUPPLIES
10'10"
14'10"
30'1"
30'1"
84'0"
SLATE ROOF
30" X 7'0"
34" X 6'0"
EAST
4'0"
3'0"
26"
George, John M.

FIG. 261.

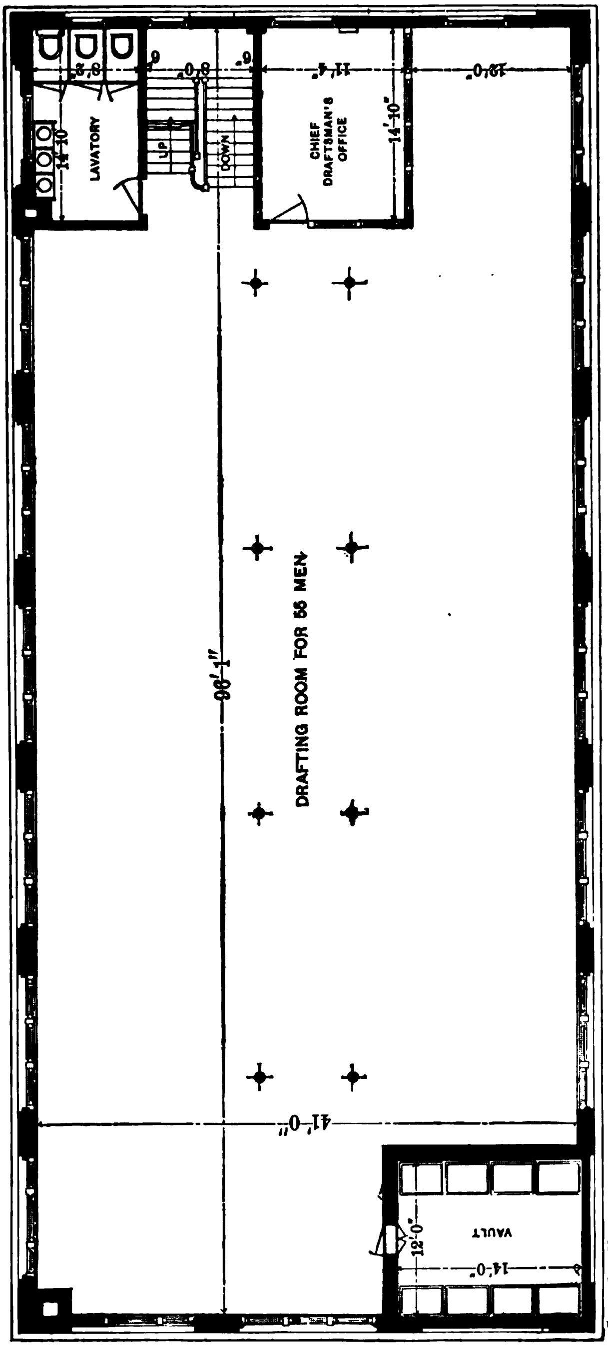

LAVATORY
UP
DOWN
CHIEF DRAFTSMAN'S OFFICE
14'-10"
14'-10"
DRAFTING ROOM FOR 55 MEN
96'-1"
41'-0"
VAULT
12'-0"
14'-0"

Fig. 262.

the tee-square, and later on with the Universal Drafting Machine, of which I shall speak further on.

We found three objections to the vertical table. Two of which are made by the draftsmen themselves, and one by the superintendent of the drafting-room. Many men object to having to hold their arms up about even with their shoulders all day long, and then again the vertical drawing board does not give the man the opportunity to have his reference drawings right around him as the horizontal board does.

The superintendent objects to them on the ground that they divide the drafting-room off into stalls.

9. Our drawing office superintendent is considering now the equipment of our new office with a table built by the Hein Furniture Company of Toledo, illustration of which is shown in Fig. 267. We are considering this table for reasons given above, and also in order that we may be equipped throughout with the Universal Drafting Machine.

A very practical question arises right here as to the number of square feet of space to be given to each man. There are three factors entering into this question. First, the convenience of the man, allowing ample room for reference drawings, etc.; second, ventilation, and third, sufficient room so that those supervising the work can get around the office without disturbing the men in passing.

We believe that it would be good business policy to allow 100 square feet for each man. The American Bridge Company, employing hundreds of men, allow considerably more space than this.

To give an idea as to how some drafting-rooms are arranged, I give a plan of one of the American Bridge Company's drafting-rooms at Toledo, in Fig. 261. In Fig. 262 is shown the arrangement of McClintock, Marshall & Co.'s offices at Pittsburg, Pa. In Fig. 263 is shown the arrangement of our new offices (which are now building). We also show the Wellman Seaver Engineering Company's office in Cleveland, Ohio, in Fig. 268.

10. In regard to sanitary arrangements, the toilet-room should be immediately off of the drafting-room. We have provided one closet to each fifteen men, and wash basins in the same proportion.

The recent developments in electric blue-printing have been a great relief to many of the large offices in the country, and as

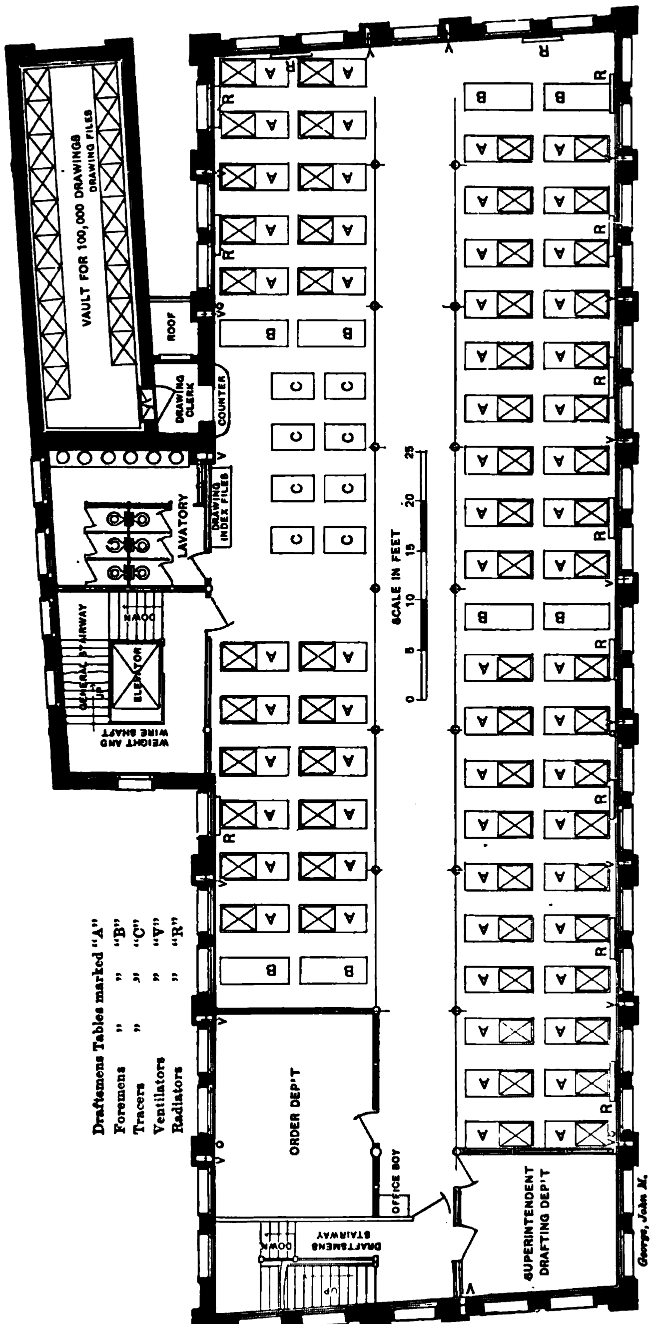

Draftsmens Tables marked "A"
Foremens " " "B"
Tracers " " "C"
Ventilators " " "V"
Radiators " " "R"
VAULT FOR 100,000 DRAWINGS
DRAWING FILES
ROOF
DRAWING CLERK
COUNTER
DRAWING INDEX FILES
LAVATORY
GENERAL STAIRWAY
ELEVATOR
WEIGHT AND WIRE SHAFT
DOWN
UP
SCALE IN FEET
0 5 10 15 20 25
ORDER DEP'T
OFFICE BOY
DRAFTSMENS STAIRWAY
SUPERINTENDENT DRAFTING DEP'T
George, John M.

FIG. 263.

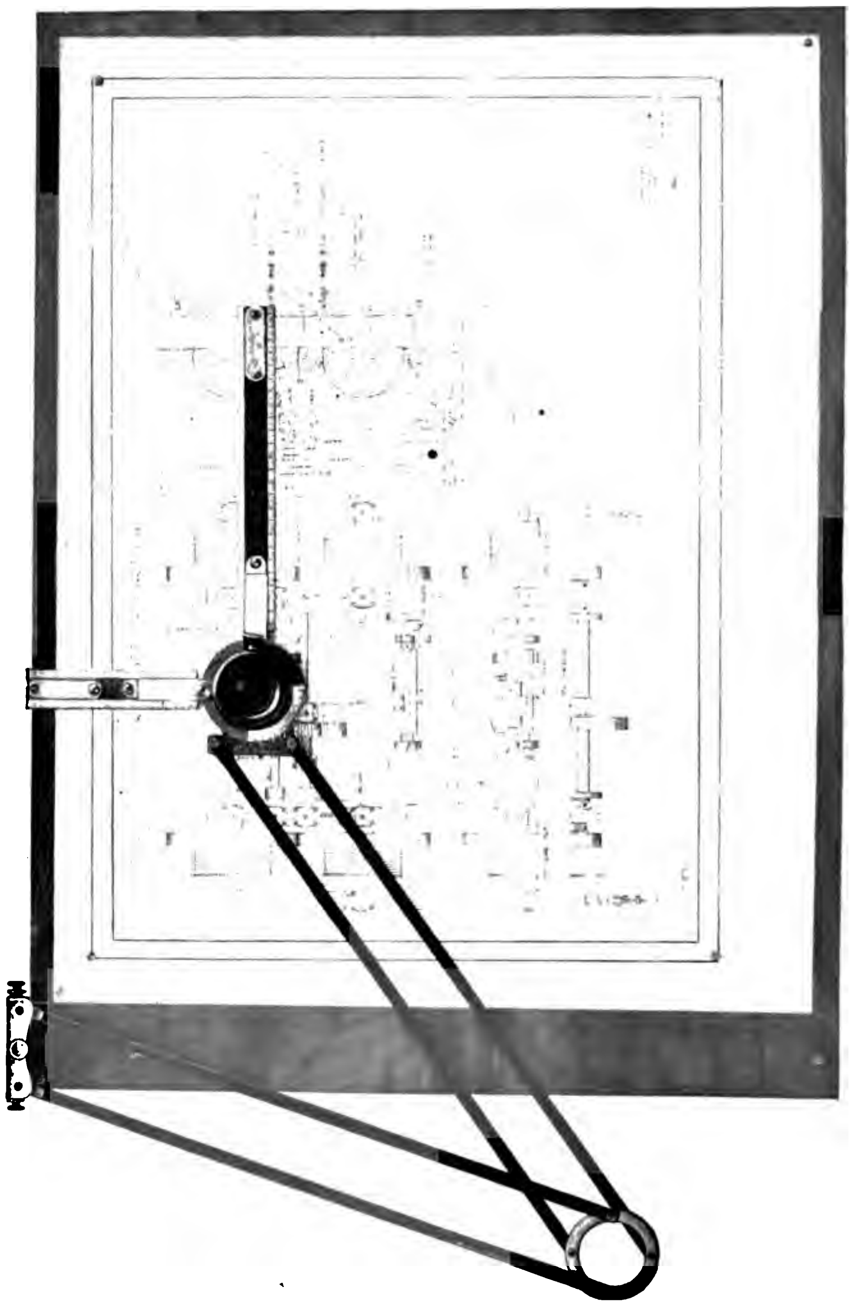


Fig. 264.

they make the blue-printing entirely independent of the weather, they are being very generally adopted.

11. I have referred to the Universal Drafting Machine, and desire to bring to your notice two forms of these machines. They are, in my opinion, the most radical departure which has been made in the drafting line, and I believe they are a very important aid to the draftsman. I am very much interested in this device, as it was designed (invented might be a better word) in our office. It was not a chance or lucky thought, as the inventor, Mr. Charles H. Little, has conferred with me many times during the past few years in regard to improvements in the drafting-room. Mr. Little had also invented a number of other very useful appliances before he brought out this machine, and I sincerely hope and expect that we shall hear from him again.

This machine is doing all that he promised for it, and something more. Fig. 264 shows one of these machines attached to a board in use on a drawing for a crane trolley, and Fig. 265 shows it in use for working out strains graphically. The machine is so exceedingly simple that it scarcely needs description. It is based on two fundamental ideas, one that all angular work must be as readily put in as straight work; and second, that we must enable the draftsman to draw and scale a line with the same edge at the same time. This applies in straight work as well as in angular work, and eliminates considerable erasing, as well as the constant changing from one tool to another. In short, work which formerly required two tools to be used on each line now requires only one, saving the time necessary to change from one tool to another. The protractor used with this machine also has a new feature, in that it is provided with spring stops for the angles most frequently used, and at the same time it may be clamped to any angle.

In actual tests made by Mr. Little he has demonstrated on both a typical mechanical and a typical structural drawing that the saving of time is very nearly the same, and amounted to 33⅓ per cent. in these two tests which were made to determine the efficiency of this machine.

Some time since Mr. Little sent out a large number of letters to many of the leading concerns using this device, asking their experience with particular reference to the time-saving feature. He received replies varying from 10 per cent. to as high as 50

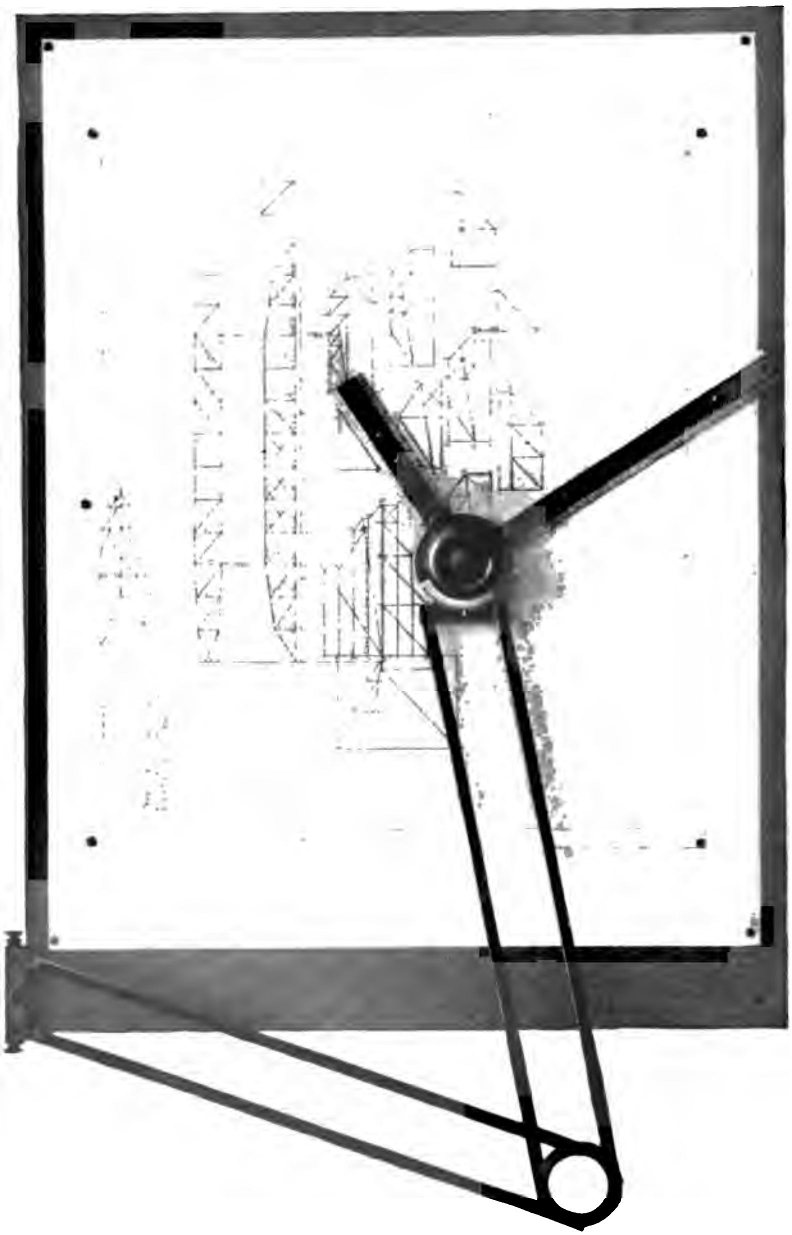


FIG. 265.

per cent., and many firms stated that they could not say what percentages they saved, as they had not given the matter close enough attention, but that they were satisfied that the saving was very considerable.

A very important feature of this device and one that seems to meet with a great deal of favor, is the fact that a draftsman can get out work very quickly when occasion requires, and it has been the writer's experience that occasion frequently does require.

In regard to the saving of time, the average of the replies received by Mr. Little show the average saving to be 25 per cent. Of course this is a matter that will vary with the different drawings, some showing a larger saving and some less, and this average seems to be the best that we can figure on, but if we place the saving at 10 per cent., this means on $50,000,000 salary a saving of $5,000,000 per year.

One of the problems which it has been necessary to contend with in this device is the extreme accuracy required. For instance, machines have been tested in which there was a variation of less than $\frac{1}{100}$ of an inch in 24 inches. As the bearings are 3 inches centre to centre, a variation of $\frac{1}{1000}$ of an inch in these 8 bearings would give a variation at the end of a 24-inch straight-edge of $\frac{1}{125}$ of an inch, and this $\frac{1}{1000}$ of an inch divided by 8 bearings would make $\frac{1}{8000}$ permissable in each bearing. That this is obtained in large quantities of machines is a rather unusual condition, and the question arises as to what effect wear will have on the accuracy of the instrument.

In reply to this question I would say that the bearings are all hardened and ground, and that the pressure and speed, which are the conditions which produce wear, are almost nothing in this device.

We have had one in use for some eighteen months, which was an experimental one and had straight, soft bearings, and these bearings do not, although they were soft, show perceptible wear after use for this length of time. We therefore conclude that the hardened bearings will last indefinitely. Another question which came up was whether or not the scales would wear when used as straight-edges, particularly at the parts of the scales which were most used. This question was first answered by saying that firms could afford to throw away the scales and purchase new ones, if such wear should take place. We, however,

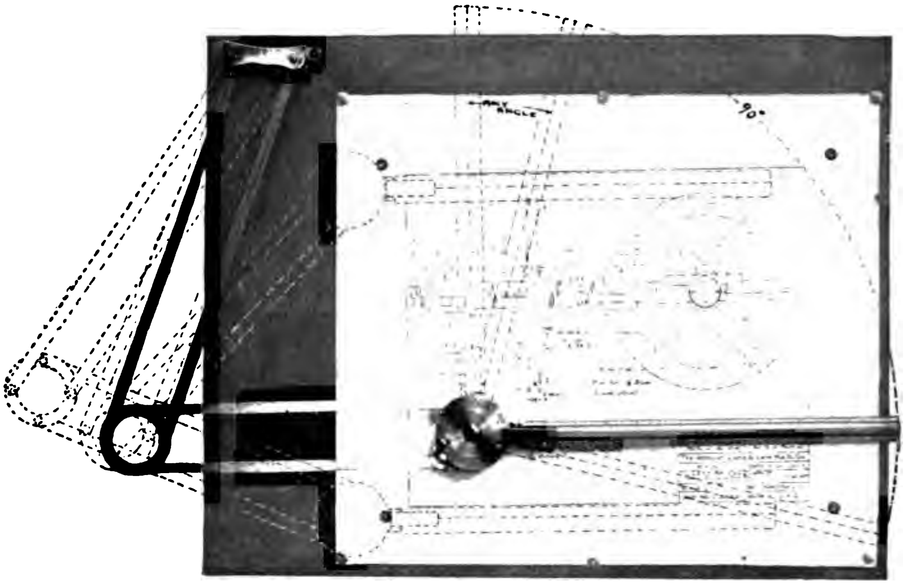


Fig. 266.

have more data now on which to base an opinion, and we find that the graphite provides a lubricant along the edge of the scale, and that they showed no perceptible wear after continued use.

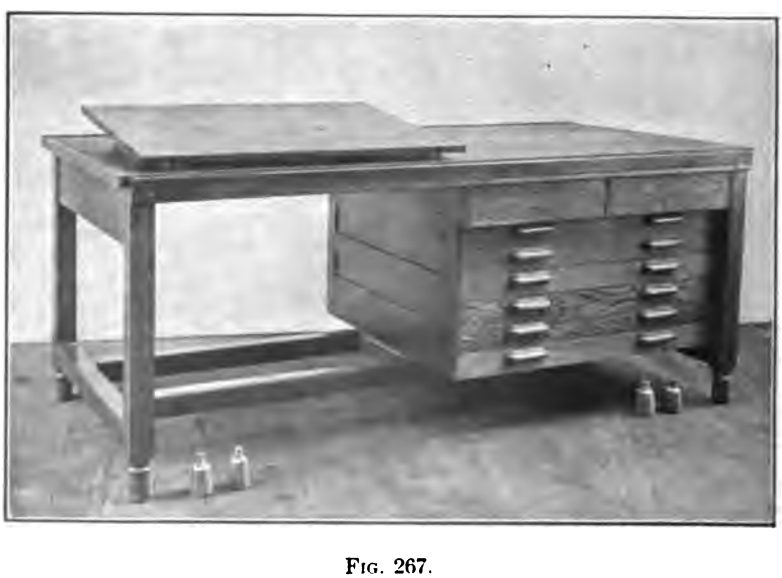


Fig. 267.

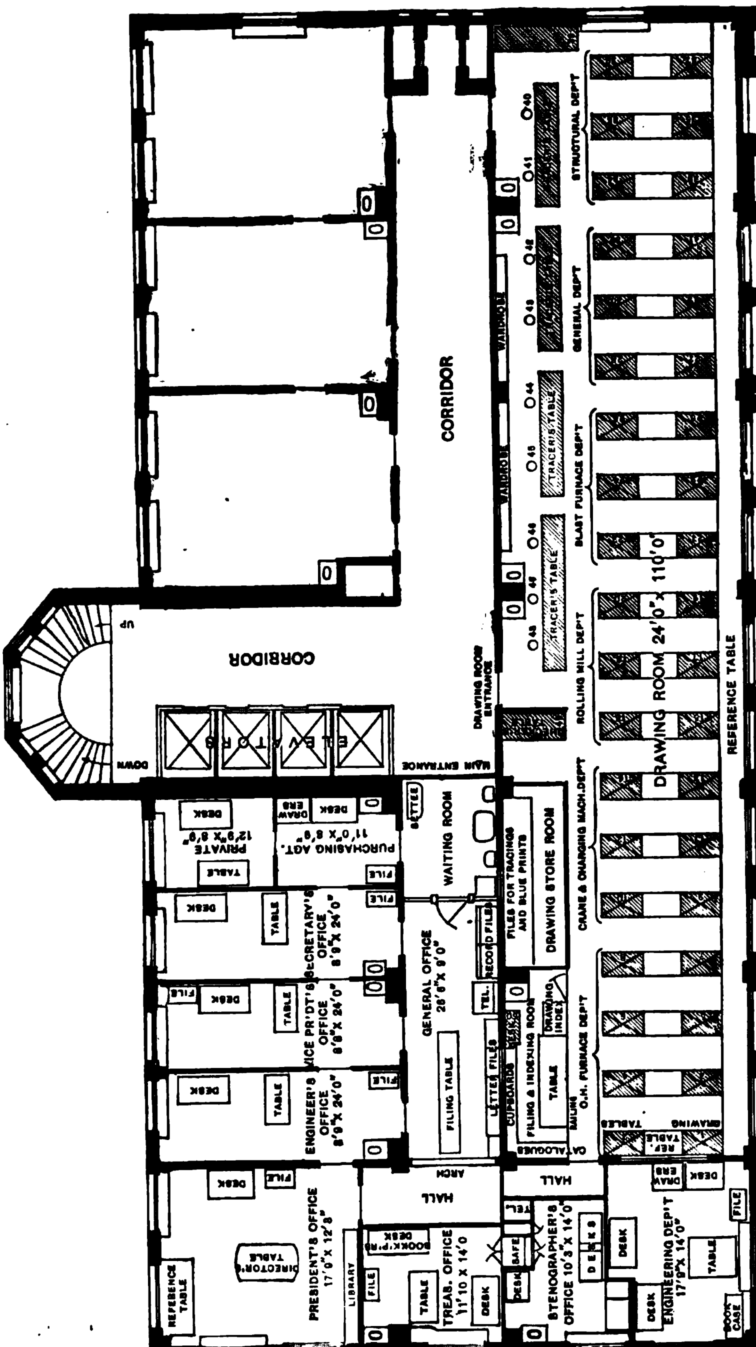


FIG. 268.

George, John M.

Mr. Little is somewhat disappointed in this respect, as he had hoped to enjoy the privilege of constantly replacing scales.

Another feature in regard to the pins in these machines shows that a device may be mechanically right and still have objectionable features. In some of these machines which were sent out, a cone joint was used providing a take-up for wear. This worked very nicely as long as properly adjusted, but many draftsmen seemed to desire to experiment on the adjustment, and not having the requisite skill to bring back so fine an adjustment, it operated to the serious disadvantage of the machine. A change was then made to straight pins, hardened and ground, and with these pins it is impossible to get the machine out of adjustment.

12. The second form of this device is what is called the Rapid Sketching Device, shown in Fig. 266. It is similar in principle to the drafting machine, but being very much smaller and used merely for the purpose of sketches, it has but one scale instead of the square as used in the drafting machine. This single scale has a free throw of 90 degrees between stops, and this 90 degrees can in turn be set at any angle. The principle of the device is simply that one using it as an ordinary scale would be used if one had the power to always place it in the desired direction without thought or effort. We believe it to be of great assistance to the engineer and the designer, and have found it very convenient for our personal use.

13. In conclusion I would draw attention to one feature we have just gotten in good working shape, although it is more strictly a question of management than equipment.

We have found that it is a great advantage to separate completely the executive management of the drawing-room from the engineering oversight, more especially as the drawing-room has changed into the engineering office of the works in every respect. Not only are drawings made there, but all orders are made out for material, etc., and oversight is exercised over the outside engineers of whom we have two classes, engineers in charge of work, and erectors putting up machinery. So that we have appointed a superintendent of the drafting office, whose business is to take entire executive charge of the men, looking after all time, salaries, drawings, blue-prints, requisitions on the purchasing department, the hiring of men, etc., leaving only the actual engineering questions to be handled by the engineers, of whom we have several. The office itself is divided into departments, each of which has a foreman (who is also a good engineer). So that the superintendent is responsible for the smooth running and the getting of the work through the office; whilst the different engineers are responsible for the engineering side of the question. This arrangement is working very well, and will work much better as all parties come to understand thoroughly just where their duties end.

DISCUSSION.

Mr. J. H. Parker.—I would like to tell the members of the Society something about a method which I have introduced in the drawing-room of the concern with which I am connected, at Baltimore, for keeping track of the constant changes that are called for in the details of their machinery. All the different parts of the machines are numbered and detailed on paper and then mounted on cardboards, 10 by 14 inches, for shop use. It is necessary to keep a file of these blueprints, and the system I refer to provides for keeping a record of the changes on these detail sheets. I have had provided large bound books, which are all indexed. When these sheets go into the shop a duplicate sheet is pasted, by one edge only, in one of these bound volumes. When it becomes necessary to make any change in any of the details it is very essential, of course, that a record should be kept of the changes; *when* the change was ordered; *why* it was ordered, and so on. This is entered on the margin of the filing-book, directly opposite the sheet. A new detail is then made and the old ones are called in. The new one is then pasted by one edge directly over the other by one edge only, as before, and new copies are sent into the shop.

Then, as time goes on, we have a complete record of all the changes which have taken place in the making of these several parts, and that record is very accessible, and it is not a complicated system by any means.

Mr. Irving H. Reynolds.—In respect to the draughting machine, it has always seemed to me that the purely manual part of a draughtsman's work is the smallest part of it. If a draughtsman has in hand a line of work which requires a maximum amount of measuring, drawing of lines, etc., with a minimum amount of brainwork, then a draughting machine will save considerable time.

Of course it is necessary to provide good light, ventilation, etc., but we can do very little for the draughtsman in the way of mechanical aids which will increase his efficiency; for, after all, it is mental equipment that is essential.

The President.—While Mr. Calder is making his sketch I might state that the system of lighting which Mr. McGeorge speaks of in his paper is very good indeed, but we have found it better to put a few drops of red in the white, as it makes a kinder light, more agreeable to the eyes.

Mr. Calder.—We all know the old-fashioned office with a dead flat roof and windows all around, where if the floor area is at all extensive the men in the centre of the room are always complaining about the light. Now, our draughting-room is arranged with the roof lights facing the north, a sawtooth roof. Of course the best system of all would be, I believe, a drawing-room having no windows at all at the sides, with walls completely around, a north light admitted from the top, and a well-controlled mechanical ventilating and heating system.

In Fig. 267 you will see that Mr. McGeorge shows a table with six drawers. Now I do not believe in these drawers. I think a man needs but one drawer as a place to keep his tools, and that any more are a hindrance, and that it is better to place his drawings on a bench underneath the table.

In regard to the isolation of draughtsmen, I do not think much of the plan proposed. I do not think the system of having men work in compartments, with partitions reaching up higher than their heads is a good idea. It shuts off ventilation and these compartments become veritable hot pockets in the summer time.

In regard to the toilet arrangements, I have been in drawing offices where if a man wanted to wash his hands he had to go down two or three flights of stairs. Now I do not think that is a good arrangement. I think a lavatory should be placed right at hand on the same floor, though I do not believe the actual toilet room should be connected with the draughting-room, for sanitary reasons.

I think the supervisor of the office should have a place partitioned off with glass, where he can have the men employed in the room in full view and where at the same time he can do his work undisturbed.

Mr. Kent.—I had occasion to go into a large draughting-room not long ago, where there were no windows, the light coming in from overhead. The ventilation in the room was excreeable; there were skylights to let air in, but the air in the room was foul, and the draughtsmen had no chance to rest their eyes by looking out—nothing but white walls to see. I think it was arranged decidedly wrong.

Mr. H. M. Lane.—I would like to inquire of Mr. McGeorge about the wearing of the joints of that draughting machine; I would like to know whether the wearing of the joints affects the action of it at all?

Mr. Dean.—As to what has been said here in reference to partitions separating the draughtsmen, I would say that Mr. Andrews, an architect of Dayton, Ohio, who designed the Cash Register factory, has all of his draughtsmen located in stalls. This only shows that some people like the plan if others do not.

Mr. E. H. Whitlock.—In regard to artificial light, I would call the attention of the Society to a new attachment that I have seen on the General Electric Company's lamps, called a Diffuser, which is sort of umbrella-shaped and about four feet diameter. It is claimed that it will absorb any color ray that might be objectionable and give back any other color ray desired.

The President.—If there is no further discussion of the paper, I will call upon Mr. McGeorge to close.

Mr. McGeorge.—There is really very little to reply to. I am glad the paper has excited the interest it has, however.

In regard to the accuracy of joints, a question in respect to which Mr. Lane inquired, I would say that we have one of the first machines ever made in use in our office to-day with soft pins and we cannot discern any inaccuracy in that machine yet. There have been some machines sent out using taper-pins in the joints, but that was given up. Now they are making them all with plain hardened pins in the joints, and it is remarkable how accurate they are even after long usage. There have been several occasions where people have complained that the machine was not accurate, but upon investigation it was found in almost every instance that the machine was not screwed well to the board.

No. 999.*

WATER AND HEAT CONSUMPTION OF A COMPOUND ENGINE AT VARIOUS POWERS.†

BY D. S. JACOBUS, HOBOKEN, N. J.
(Member of the Society.)

1. THE engine on which the test was made was located at the Brooklyn plant of the American Sugar Refining Company. It is manufactured by the Providence Engineering Works and was of the Rice and Sargent horizontal cross-compound type, provided with a Corliss-valve gear. The principal dimensions, measured when hot, were

Bore of cylinders	20.08 and 40 inches.
Length of stroke for each piston	42 inches.
Diameter of piston rods	3.5 and 4.75 inches.

The average clearance for each end of the cylinder was 4.7 per cent. for high pressure cylinder, and 7 per cent. for the low pressure cylinder.

The engine was provided with a reheater coil in the receiver, which was supplied with steam at boiler pressure. The cylinder heads of both high and low pressure cylinders were jacketed with high pressure steam. The condenser was of the Bulkley type. The engine ran at about 120 revolutions per minute, and was directly connected to an electrical generator. The steam pressure averaged about 150 pounds per square inch above the atmosphere, and there was an exceptionally good vacuum.

2. The principal results of the test are given in Table I. The water consumption of the engine per indicated horse-power per hour, as given in the 11th column of this table varied from 12.10

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

† For further references on this subject, see *Transactions* as follows:

No. 208, vol. ix., p. 545: "Memoranda on Performance of Compound Engine." Geo. H. Barrus.

No. 620, vol. xvi., p. 179: "Test of Compound Engine." F. W. Dean.

pounds at 627.4 horse-power to 12.75 pounds at 1,004.3 horse-power. At 491.4 horse-power the water consumption was 13.92 pounds, and at 339.7 horse-power it was 14.58 pounds. These figures represent the total water consumption, including that used by the jackets and reheater coil. The heat consumption in British thermal units per indicated horse-power per minute, is given in the 12th column of the table. This heat consumption is computed according to the standard recommended by the Civil Engineers of Great Britain, where the engine is credited with the maximum temperature at which it could return the water to the boiler. The results varied from 222.7 British thermal units per minute per indicated horse-power at 627.4 indicated horse-power to 231.8 at 1004.3 indicated horse-power and 267.7 at 339.7 horse-power.

TABLE I.

FINAL RESULTS OF TESTS.

Order of Tests Based on the Amount of Power Generated.

Number of Test.	Date of test, 1901, 1902.	Length of test in hours and decimals of an hour.	Average steam pressure by gauge near throttle valve in pounds per sq. in.	Average vacuum in inches of mercury.	Average reading of barometer in inches.	Average pressure above zero in condenser in pounds per sq. in.	Average temperature of engine room in degrees Fahrenheit.	Revolutions per minute.	Indicated horse-power.	Water consumption in pounds per hour per I. H. P.*	Heat consumption in B. T. U.'s per I. H. P. per minute.
1	2	3	4	5	6	7	8	9	10	11	12
2	Dec. 27th	6.95	148.0	27.65	30.16	1.25	90.7	120.56	1004.3	12.75	231.8
1	Dec. 26th	5 19	149.8	28.22	30.25	0.99	97.8	120.92	853.3	12.33	226.3
4	Dec 30th	8.00	149.9	27.33	29.69	1.16	82.5	121.17	819.6	12.55	229.9
3	Dec. 28th	8.75	151.3	28.63	30.37	0.85	96.0	121.52	627.4	12.10	222.7
6	Jan. 2d	8.17	150.1	28.77	30.44	0.82	87.7	121.94	491.4	13.92	256.8
5	Dec. 31st	7.30	150.1	27.98	29.86	0.92	89.8	122.67	339.7	14.58	267.7
7	Jan. 2d	Friction diagrams; dynamo running idle.						122.00	45.0		

* Total including that consumed by jackets and reheater coil.

3. Fig. 269 shows some of the principal results graphically. It will be seen that all the results fall well in line with the exception of two tests, Nos. 5 and 6, which were made at the lighter powers. The reason for the variation from the curve in these two tests is that it was impossible to prevent an excessive steam pressure in the boilers, which were operated by Roney stokers, without opening side doors in the boiler setting and admitting cold air above the grates. This produced erratic readings of the

water levels in the boilers, and made it impossible to obtain as close results as in the other tests where the side doors were not opened. There were loops formed at the lower ends of the expansion lines of the indicator diagrams of the high pressure cylinders in the two tests where the power was the lightest.

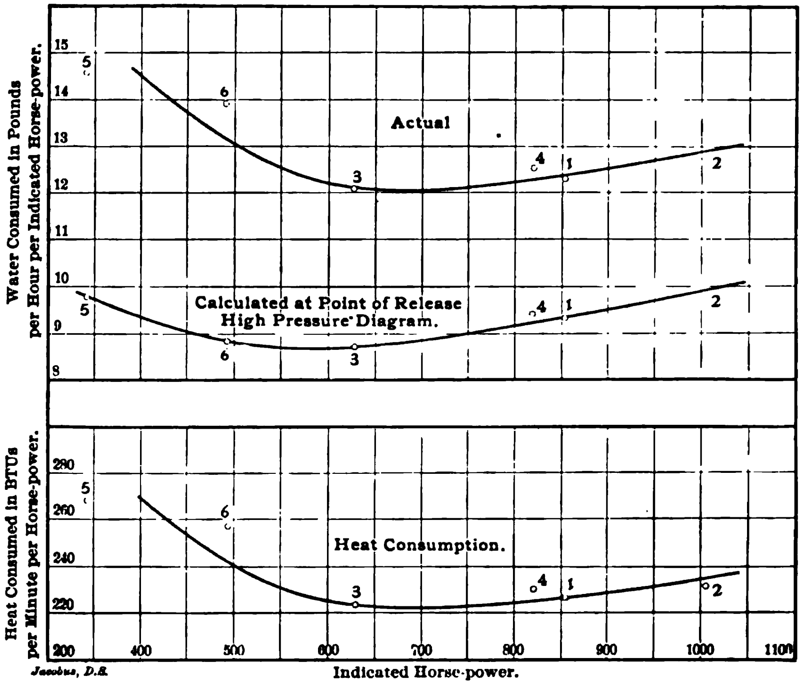


FIG. 269.—CURVES SHOWING THE WATER AND HEAT CONSUMPTION PER INDICATED HORSE-POWER.

4. The water consumption was determined by weighing the feed water supplied to two Babcock & Wilcox boilers which furnished the steam. All water and steam connections where leakage would not be apparent were blanked off. The feed-pump was supplied with steam from an independent source of supply so that all the steam generated by the two boilers passed to the engine.

5. Before starting to take the readings for a test, the engine was run for an hour or more to make sure that uniform conditions were secured. If the first readings were not uniform, the start was delayed until such was the case. The amount of water fed each hour was determined, and the tests were made of such a

length that they could be divided into several intervals, which gave results agreeing very nearly with each other. The water at the boilers was balanced up in two ways at each hourly interval. The first balance was made by running the feed-pump as uniformly as possible and keeping the water at a given level. After securing this reading, the water level was raised in the boilers, the pump stopped, and the time taken when the water reached the given level. The rates of feed water furnished to the boiler were found to be more uniform by the second method than by the first, and the readings based on the second method were, therefore, used in the computations.

6. The weight of drip water from the jackets and from the receiver coil was determined in tests Nos. 4, 5 and 6. A special test was made to determine the amount used for the conditions which existed in test No. 1. In tests Nos. 2 and 3 the amount of drip water was determined by basing it on the results found in the tests where it was measured. The amount of drip water is one of the factors entering the computations of the heat consumption which are given in Table II. Any error in the amounts of drip water in those tests where it was estimated from the amount found in other tests will affect the final result but little, as an error in the drip water amounting to 10 per cent., or about 1 per cent. of the total feed water, will cause an error of but $\frac{1}{8}$ of 1 per cent. in the figure for the heat consumption.

7. The quality of the steam was measured by means of two Barrus throttling calorimeters attached to nipples entering the steam main at points near the throttle-valve. There was a separator in the steam main through which the steam passed before reaching the calorimeters. The steam supplied to the engine was found to be dry. Any water separated from the steam by the separator was deducted from the feed water in order to obtain the net feed water used by the engine.

8. The electrical power generated by the engine was absorbed by two water rheostats, in each of which two plates of boiler steel were suspended in salt water. These plates were about 2 feet wide, 3 feet deep and $\frac{1}{2}$-inch in thickness. Both of the rheostats were used in the tests with heavy loads, and but one in the tests with light loads. The plates lost weight rapidly when in use, and it was necessary to renew them several times before the series of tests were completed.

9. The indicator springs were carefully calibrated, and the

TABLE II.

COMPUTATION OF THE HEAT CONSUMED IN B. T. U'S. PER MINUTE PER INDICATED HORSE-POWER.

Order of Tests Based on the Amount of Power Generated.

NUMBER OF TEST.	Temperature of steam in condenser in degrees Fahr.	Total feed-water used by the engine in pounds per hour.	Water from jackets and reheater coil in pounds per hour.	Temperature of water from jackets and reheater coil in degrees Fahr.	Weight of water fed at temperature given in Col. 2 = Col. 3 − Col. 4. *Lbs.*	Temperature of feed-water if water from jackets, etc., mingles with the main supply of feed-water (Col. 6 × Col. 2 + Col. 4 × Col. 5) ÷ Col 3. *Dg. Fahr.*	Heat imparted to one pound of feed-water above the temperature given in Col. 7. *B. T. U.*	Heat imparted to feed-water per hour per horse-power. (Water per hour per horse-power) × (value in Col. 8). *B. T. U.*	Heat consumption in B.T.U'S. per minute per horse-power = Col. 9 ÷ 60.
1	2	3	4	5	6	7	8	9	10
2	109.0	12,803	1,475.0	326.1	11,328.0	134.0	1,090.9	13,909	231.8
1	101.6	10,520	1,042.0	326.1	9,478.0	123.8	1,101.5	13,581	226.3
4	107.0	10,283	938.4	314.3	9,344.6	125.9	1,099.4	13,797	229.9
3	96.6	7,591	815.0	326.1	6,776.0	121.2	1,104.8	13,862	222.7
6	95.4	6,840	737.7	307.3	6,102.3	118.3	1,107.1	15,410	256.8
5	99.2	4,953	492.4	346.4	4,460.6	123.8	1,101.5	16,060	267.7

equivalent scales corresponding to the cards for each test were determined by the standard method, which allows for all variations. The equivalent scales were found to be practically uniform for the high pressure diagrams, and were so taken, whereas for the low pressure diagrams it was necessary to employ a different scale for each test.

The platform weighing scales used in the tests were calibrated with United States standard weights to the maximum weight to which they were subjected.

Average indicator cards and combined diagrams are given for the tests where the maximum power was developed, where the maximum economy was obtained and where the minimum horse-power was developed; these are numbered Figs. 270 to 272 inclusive.

10. Table III. gives the average mean effective pressures and computations of the horse-power. Table IV. contains computations of the water consumption from the high pressure indicator diagrams. The percentage of steam not accounted for by the indicator less that consumed by the jackets and reheater coil may not be as accurate in tests 1, 2 and 3 as in the others,

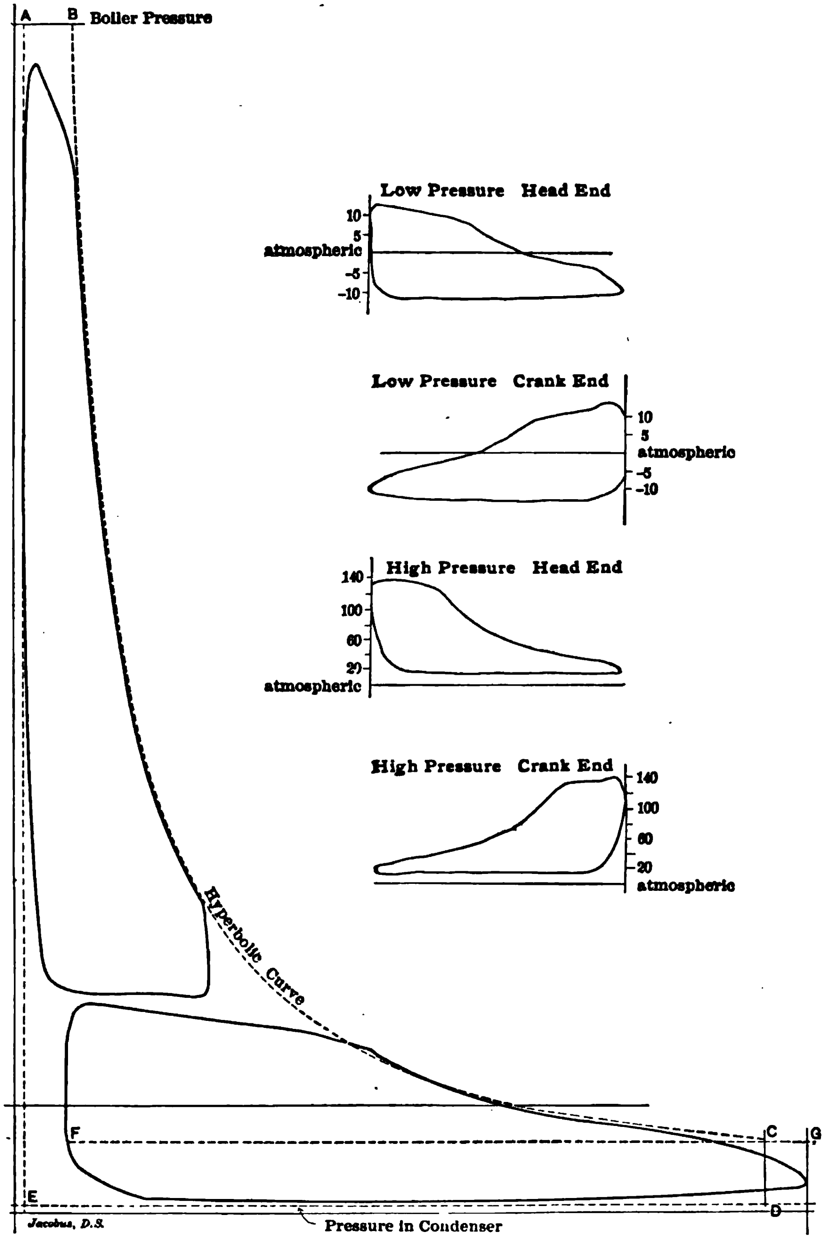


FIG. 270.—INDICATOR CARDS AND COMBINED DIAGRAM FOR TEST NO. 2.

Test with heaviest load:

$$\text{Diagram Factor} = \frac{\text{Area of Indicator Diagrams}}{\text{Area ABCDE}} = 83 \text{ per cent.}$$

$$\text{Ratio of Expansion} = \frac{FG}{AB} = 16.$$

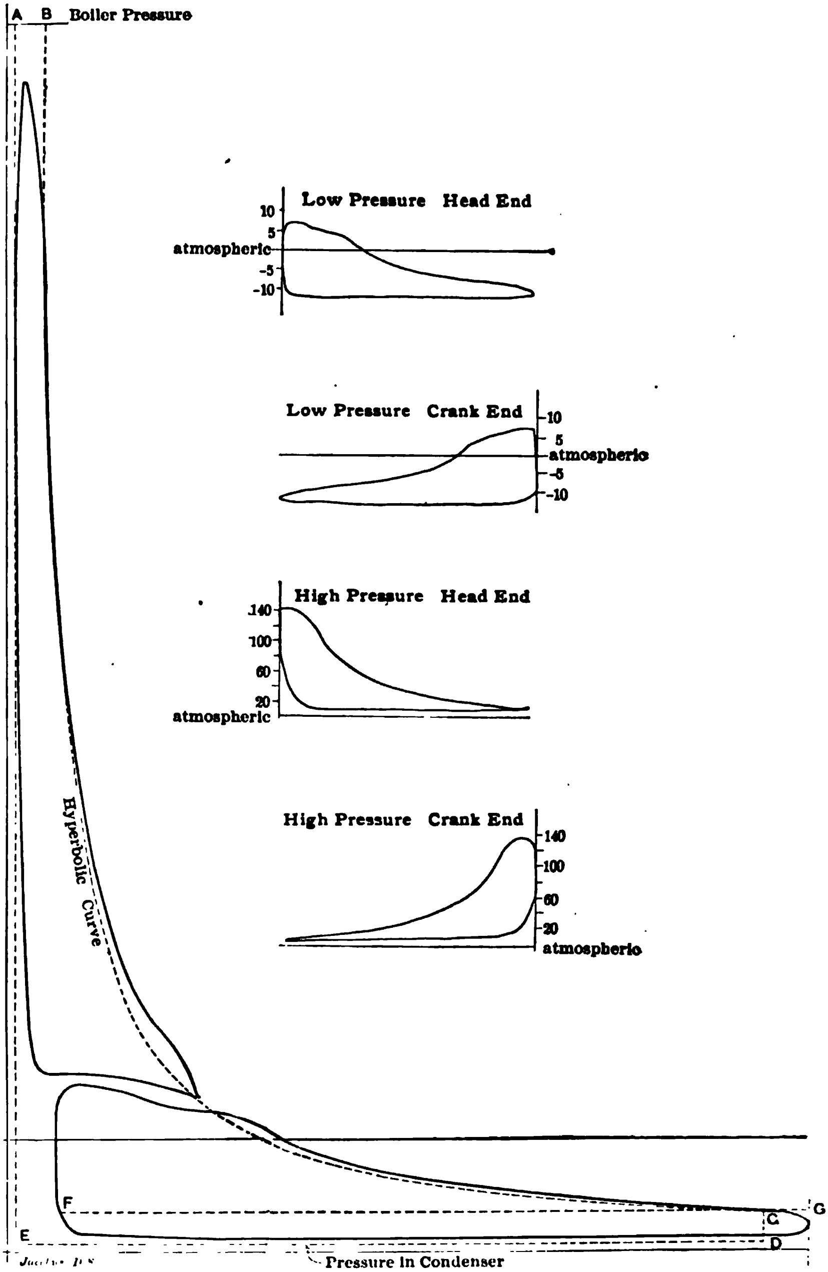


FIG. 271.—INDICATOR CARDS AND COMBINED DIAGRAM FOR TEST No. 3.

Test where the maximum economy was obtained:

$$\text{Diagram Factor} = \frac{\text{Area of Indicator Diagrams}}{\text{Area ABCDE}} = 89 \text{ per cent.}$$

$$\text{Ratio of Expansion} = \frac{FG}{AB} = 33.$$

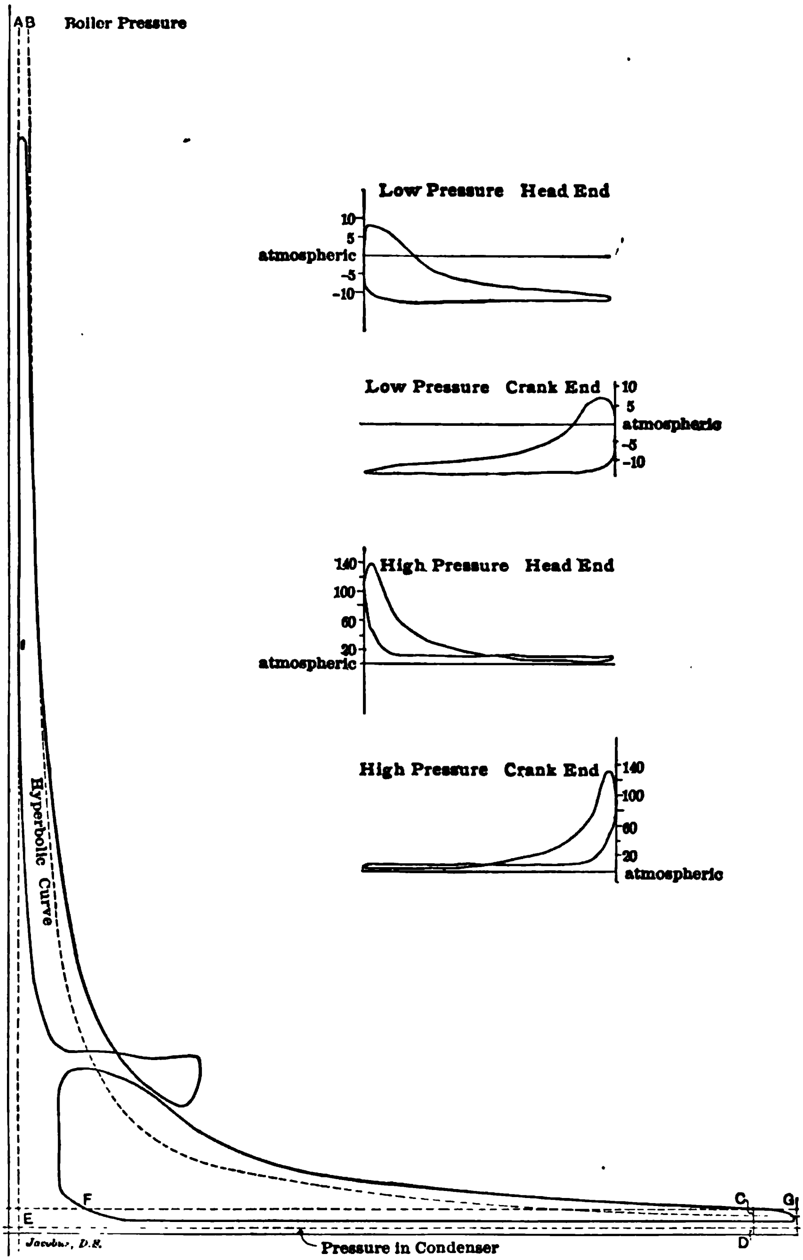


FIG. 272.—INDICATOR CARDS AND COMBINED DIAGRAM FOR TEST No. 5.

Test with lightest load:

$$\text{Diagram Factor} = \frac{\text{Area of Indicator Diagrams}}{\text{Area ABCDE}} = 95 \text{ per cent.}$$

$$\text{Ratio of Expansion} = \frac{\text{FG}}{\text{AB}} = 69.$$

because in these tests the steam consumed by the jackets and the reheater coil was not measured but was estimated from the results of tests made under similar conditions.

TABLE III.

Mean Effective Pressures and Horse-powers.

Horse-power constants for high-pressure cylinder = (revolutions per minute × 0.03342) for head end; and (revolutions per minute × 0.03240) for crank end.

Horse-power constants for low-pressure cylinder = (revolutions per minute × 0.1333) for head end; and (revolutions per minute × 0.1314) for crank end.

Number of Test.	Ave. M. E. P.; high pressure cylinder.		Low-pressure cylinder.				Revolutions of engine per minute.	Horse-power of high-pressure cylinder.			Horse-power of low-pressure cylinder.			Total indicated horse-power.
	Head end scale = 99.0.	Crank end scale = 98.8.	Head end.		Crank end.			Head end.	Crank end.	Sum.	Head end.	Crank end.	Sum.	
			Scale.	Aver. M.E.P.	Scale.	Aver. M.E.P.								
2	61.78	61.54	20.11	16.11	20.19	16.17	120.56	248.91	240.38	489.29	258.89	256.13	515.02	1004.3
1	52.27	53.88	20.20	13.58	20.27	13.52	120.92	211.22	209.14	420.36	218.10	214.83	432.93	853.3
4	49.50	49.54	20.18	13.50	20.28	12.98	121.17	200.48	194.49	394.97	218.03	206.64	424.67	819.6
3	37.42	38.14	20.24	10.14	20.40	10.08	121.52	151.96	150.16	302.12	164.27	160.98	325.25	627.4
6	25.25	24.18	20.35	8.89	20.42	9.27	121.94	102.89	95.54	198.43	144.46	148.51	292.97	491.4
5	15.15	13.57	20.32	7.11	20.46	6.66	122.67	62.11	53.94	116.05	116.25	107.36	223.61	339.7
7	1.39	1.28	20.32	1.08	20.48	1.04	122.00	5.67	5.06	10.73	17.56	16.67	34.23	45.0

TABLE IV.

Steam Consumption Computed from Indicator Diagrams of the High Pressure Cylinder.

The Average Data from Five or More Sets of Diagrams are used in each Computation.

Number of Tests.	Steam consumption computed from indicator diagrams in pounds per hour per horse-power.		Total feed water consumed in pounds per hour per horse power.	Percentage of total feed water used by jackets and reheater coils.	Percentage of total feed water not accounted for by indicator diagrams = total percentage not accounted for, less that used by the jackets and reheater coils.	
	Near cut-off.	Near release.			Near cut-off.	Near release.
2	9.83	9.85	12.75	11.5	11.4	11.2
1	9.60	9.37	12.33	9.9	12.3	14.1
4	8.92	9.45	12.55	9 1	19.9	15.6
3	8.17	8.73	12.10	10.7	21.8	17.2
6	7.44	8.83	13.92	10.8	35.8	25.8
5	6.79	9.77	14.58	9.9	43.5	23.1

DISCUSSION.

Mr. Rockwood.—This paper appears to be purely a record of observed facts, and not to be controversial in any way, although bearing upon the subject of compound-engine design with much force. It is simply a statement of what Professor Jacobus found in these tests; and as I am sure there is no more competent tester of engines in the world than Professor Jacobus, these results ought be of substantial value. I should like to offer a few remarks suggested by the values as presented.

In the first place the economy of steam is very high. It is noticeable that it was obtained while exhausting into a very unusually good vacuum, namely, 28.63 inches. I have always believed that the highest economy of coal comes with the highest degree of vacuum. There was a heresy, widespread at one time, that the medium vacuum—24 to 26 inches—gave the best results. The idea was based on the possibility of obtaining hotter feed-water from the hot-well with the higher condenser temperature. A few months ago I crossed the Atlantic on a steamship where they were running 10,000 horse-power, and the engineer told me that he was endeavoring to carry only 24 inches of vacuum for the sake of the hotter feed-water this gave him, thus wholly ignoring the waste of power due to the extra back pressure in the condenser. Another consideration influencing the advocates of this low-vacuum theory is the reduction in temperature range in the low-pressure cylinder accompanying the low vacuum.

It has been my belief that, notwithstanding these disadvantages, the extra useful work performed in the low-pressure cylinder by the higher vacuum (provided it does not cost too much to obtain this higher vacuum) will more than compensate for the losses by cooler feed-water and greater temperature range. All the best work done with pumping-engines—of the Allis, Seron and Leavitt types—has been done with the highest vacuum, and now these Jacobus tests still further bear out this view.

The next interesting point about the plant tested is the type of condenser used to get the high vacuum recorded—that is, the Bulkley injector-condenser. I have lately been interested in getting the best condensing plant for a steam turbine. The builders of the turbine advise a very heavy expenditure of money on a surface condenser, or a "barometric" condenser, operated by a double-stage dry-vacuum pump at a cost of $2,500, when a Bulkley condenser plant can be installed for less than half that sum. Moreover, the turbine does not have the disadvantage of air leaks around piston-rods and valve-stems as this engine has; yet, here in this paper, it is stated that, with the leaks inseparable from piston-rod and valve-stems, and long runs of exhaust and water-supply pipes, the vacuum obtained was as high as can be depended upon with the best double-stage dry-vacuum pump arrangement, with its high cost for power to operate it.

Another matter of considerable general interest upon which the data in the paper bear is the question whether it is wise to install a comparatively large engine for a given power requirement, thereby getting a somewhat reduced steam consumption per indicated horse-power per hour, or to buy a smaller engine on account of its lesser first cost.

In the case before us Professor Jacobus found that when the engine works at the rate of 1,004 indicated horse-power it uses 12.75 pounds per indicated horse-power per hour, and when it is loaded to a little more than one-half that rate—627 indicated horse-power—it uses but 12.1 pounds. The larger engine is thus more economical of fuel when under loaded than when full loaded. But the question to be answered by the purchaser of an engine is whether the larger engine will earn enough by its savings in coal to warrant its extra cost.

It will save the difference between 12.76 and 12.1, as compared with 12.76, or 5 per cent. of its coal. The total coal consumption during running time will be at $\frac{12.76}{10} \times 1{,}004 \times 10 \times 310 =$ about 2,000 tons. This, at $4.00 a ton, will cost $8,000. The saving, therefore, will be 5 per cent. of $8,000, or $400 per annum. The difference between the cost of an engine of 1,004 horse-power and one of 627 horse-power, at $22.00 at horse-power, would be $377 \times 22 =$ $8,294. There will, however, be a difference of about 20 horse-power in the friction loads of the two engines. This, at the same cost for power, reduces the apparent saving of $400 to $240; and the net earning of the larger engine is but 3 per cent. on the extra first cost, to say nothing of extra oil, waste and attendance.

It is, however, some satisfaction to know that there is any saving at all when one feels obliged, in view of future extensions, to provide more engine-power than he would otherwise.

Mr. C. V. Kerr.—As long as this condenser question has come up I want to call the attention of the meeting to a note which I gathered from the Hartford Electric Light Works during the last winter. They have a Worthington condenser there, run in connection with a cooling tower and centrifugal pumps. In the summer time the vacuum ran from 26¾ inches to 27½ inches, with 82 degrees of circulating water, and in the winter from 28 to 29 inches. This vacuum is measured by a mercury column attached to the exhaust-pipe, perhaps 20 feet from the turbine. This is a 1,500-turbine which is used in connection with the power plant. The vacuum mentioned is 28.6 inches, I believe, and, if the engineer did not fail in his recollection of the exact figure, here is one 29 inches, which is a little higher than that given. In this case there is, I believe, a two-stage air-pump used in connection with the condenser, which probably accounts in part for the high vacuum. It should be noticed, also, that there is a difference in the vacuum between summer and winter.

Mr. J. S. Coon.—On this subject of condensers, I would call the attention of the gentlemen here to the plant of the Manhattan Elevated Railroad in New York City. On Monday of this week I was in their station looking around, and Mr. Tomlinson, the Chief Engineer, told me that they had made some careful experiments to determine the loss of pressure on the exhaust-pipe, between the cylinder and the condenser, and he made the astonishing statement that that loss of pressure was a pound and a quarter in a 30-inch steam-pipe at a point near the cylinder and a point near the condenser. I suppose many of you gentlemen are familiar with the construction in that station and know that the exhaust-pipe goes a distance of 60 or 70 feet—a 30-inch pipe —from the low-pressure cylinder to the condensers down underneath the engine-room floor. They are now taking out all of those condensers, the air-pumps being driven by electric motors, and substantially a modified Bulkley condenser—modified to the extent of having the air-pump attached to it—is being placed right up against the cylinder, so that they will get rid of the pound and a quarter loss in the steam-pipe. The vacuum obtained in both cases is about 28½ inches. The injection of the water is forced to the condenser by a circulating pump driven by a Ball engine. The exhaust from the engine is put into the receiver between the two cylinders. The fall between the condenser and the out-take is over 30 feet, being sufficient to maintain the vacuum. The astonishing thing to me about the plant was the enormous loss of pressure between the cylinder and the condenser, but Mr. Tomlinson says that they expect to get at least 12 per cent. increase in the power of the engines, and a corresponding increase in economy by the changes that they are now making.

Mr. F. R. Low.—I think Mr. Coon has left out the most interesting feature of that plant, and that is, that Mr. Tomlinson is arranging so that he will be prepared to discharge the dry-air pump into the tail pump.

Mr. Albert A. Cary.—According to my understanding, the condensing water used in the station just referred to is salt water obtained from the East River. The resulting mixture, consisting of the condensed steam from the engine and the salt water from the river of course, is useless for boiler feed-water, and, therefore, all of the water supply must be drawn from the city mains which results in a considerable item of expense in these very large stations.

This brings before us the much-debated question occurring in these New York water front stations, as to whether it is more desirable to use this or a jet form of condenser and throw away the condensed steam, or else to use a surface condenser and save this water with its contained oil for boiler feeding, and depend upon some one of the numerous so-called oil-separators to protect the boilers from disaster.

There are stations on the water front where they are following this last described practice with seemingly good success, and it would be very interesting to know the comparative cost of keeping the boilers in repair in the stations using each of these forms of condensers.

*Professor Jacobus.**—I thank the gentlemen for their kind discussions, to which there is little I need reply to or add.

The vacuum to give the highest coal economy depends on the ratio of expansion. Where there is a low ratio a very high vacuum may not be as economical as a somewhat lower one, but with a high ratio and a correspondingly economical engine the greater the vacuum, within ordinary limits, the greater the economy.

The condensing water for the Bulkley condenser was supplied from the city service, and the inlet valve was adjusted to give

---

* Author's Closure, under the Rules.

the best vacuum. In the tests this water was wasted, but under working conditions it is used in the refinery. On comparing this condenser with one of the surface condensing type, the fact that a pump often has to be used to raise the cooling water to it must not be lost sight of.

There is one feature which should have been mentioned in the paper which was omitted; this is, that the valve-gear was adjusted once for all before starting the test and was not altered in any way during the tests. As stated in the paper, there were loops at the lower ends of the expansion lines of the indicator diagrams of the high-pressure cylinder in the two tests where the power was the lightest. These loops could have been avoided if the valve-gear had been adjusted before making the tests at the low powers, but as the work ordinarily placed on the engine caused sudden variations in the power, the valve-gear could not be adjusted while running in regular service, and this was, therefore, not done in the tests. Had the valve-gear been adjusted so as to avoid the loops, the water consumption would probably have been more economical in the two tests at the low powers than that which was found.

The indicator diagrams, Figs. 270 to 272 inclusive, have not been reproduced exactly, and the lines in the cuts are irregular; whereas the original cards were smooth and symmetrical. It is not apparent on the combined diagrams how the point G is located. This is found by extending the expansion line of the low-pressure cylinder, according to the hyperbolic law, until it intersects a vertical line passing through the end of the diagram.

No. 1000. *

DESCRIPTION OF SIXTY-FOOT VERTICAL BORING AND TURNING MILL DESIGNED BY JOHN RIDDELL FOR GENERAL ELECTRIC CO.

BY JOHN RIDDELL, SCHENECTADY, N. Y.
(Member of the Society.)

1. THE mill herein described was made necessary owing to the constantly increasing dimensions of dynamo electric machines. On account of its immense proportions and weight of material, it was deemed necessary to build it in the factory where it was to be used, and it has been suggested by several disinterested parties that a general description of the machine would be of interest to the members of the American Society of Mechanical Engineers, or any others interested in large machine work.

Possibly the best way to describe this machine would be to start with the foundation.

Foundation.

2. This is shown in section in Fig. 273, which also shows a section through the whole machine. From the floor line to the bottom of foundation is 22 feet 6 inches.

When the excavation was made for this foundation a bed of quicksand was struck at the depth of 8 feet, which rendered it necessary to have a steel tank, 9 feet in diameter by 12 feet $9\frac{1}{2}$ inches in height, sunk to keep back the sand and water. It was found impossible to sink this tank by the regular method of digging, and the hydraulic process of sinking was resorted to. After the tank was in place, as much earth as possible was removed from the outside, gradually rounding the bottom up toward the outer edge of the foundation, the object being to keep the bottom of

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions.*

the foundation in as nearly a semi-spherical form as possible, the idea being that in settling it would adjust itself in a solid mass. In building the foundation the advantage of having an ample number of passageways of liberal size was taken into consider-

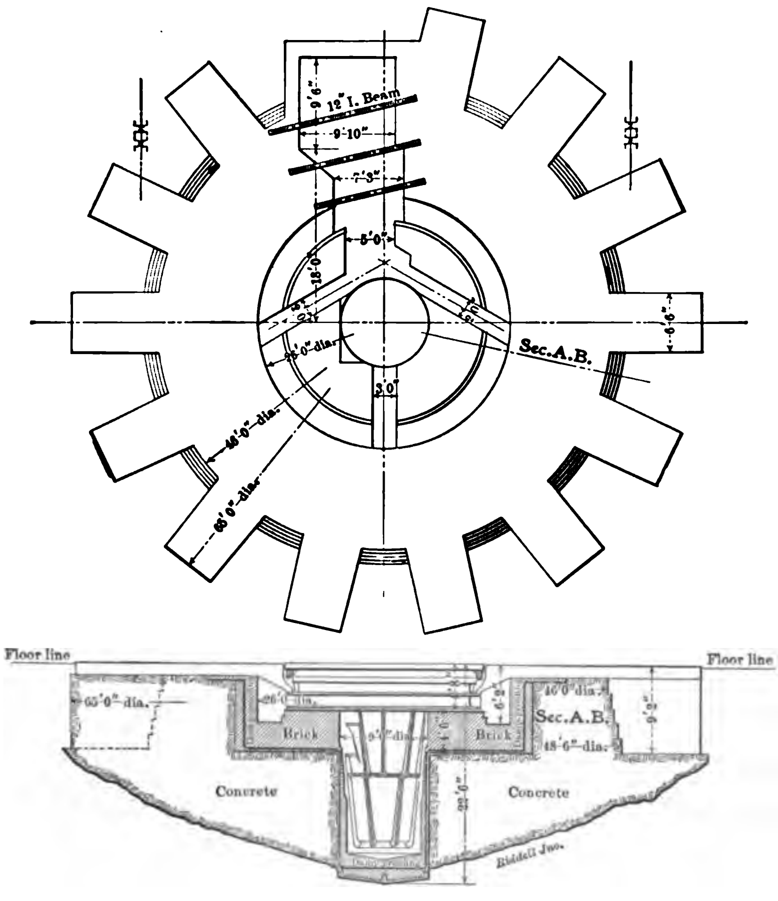


FIG. 273.

ation, with the result that the working parts of under side of mill are comparatively of as easy access as the parts above the floor. See Fig. 274.

Bed Plate.

3. The bed plate is 20 feet in diameter, and for convenience is made in three pieces, one pattern only being necessary, each

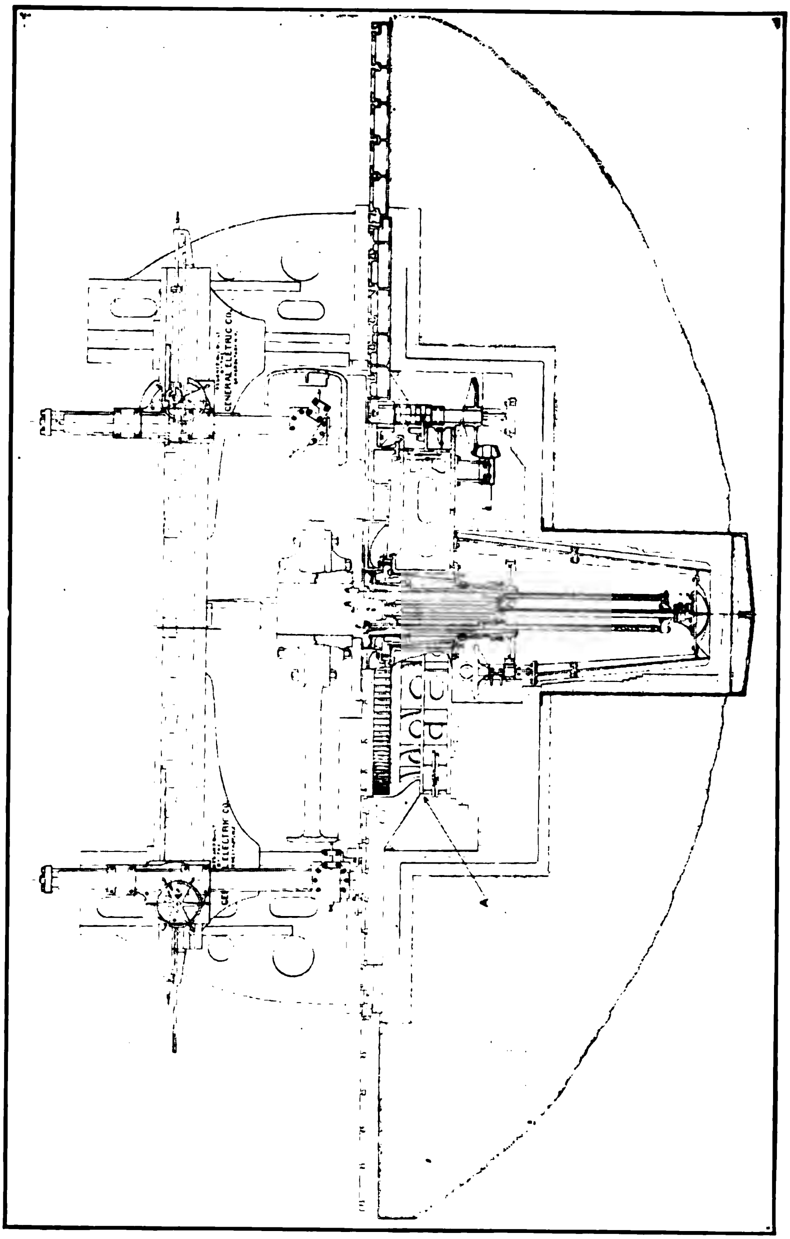


FIG. 274.

segment weighs 26,900 pounds, making a total for bed plate of 80,700 pounds. The bed plate has two ways for table to revolve upon, the centre of outside way is 17 feet 6 inches in diameter and is 10 inches wide. The centre of inside way is 5 feet diameter and is 6 inches wide. The outside way has a bearing surface of 6,600 square inches, and the inside way a bearing surface

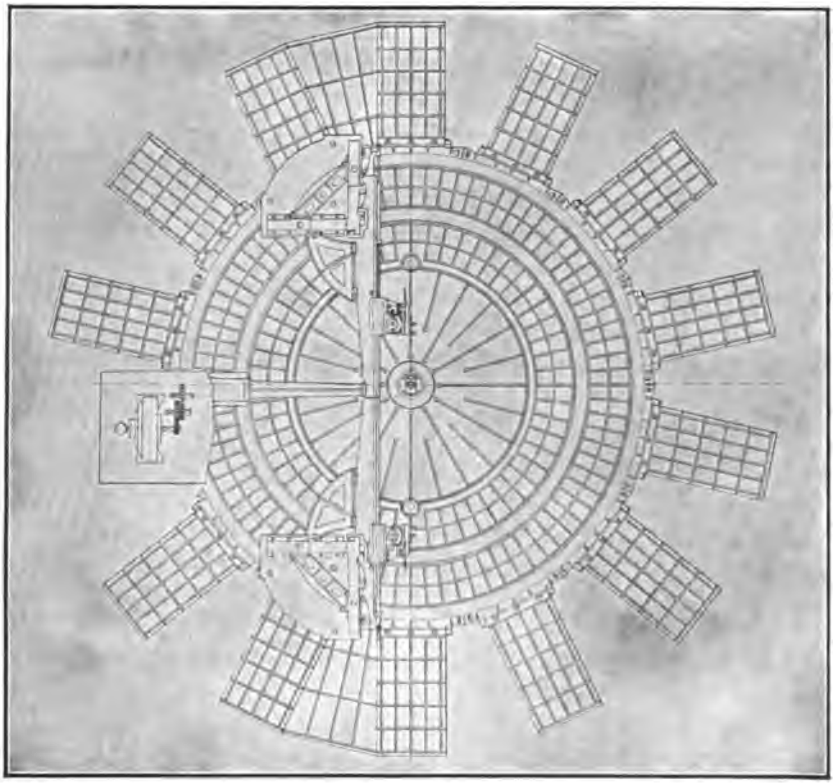


FIG. 275.

of 1,130 square inches, making a total bearing surface for table of 7,730 square inches. The maximum approximate total weight including table that the bed plate is expected to carry is 300 tons, thus making a pressure of 77.6 pounds per square inch. It is also bored out in the centre to a diameter of 4 feet to receive the main bearing for table spindle. It has a projecting shelf or flange around entire periphery, faced on upper side to form a support for floor plates, Fig. 275, which are bolted securely to the same, and is also faced on bottom to form seat for bar support.

4. Ample means are provided for oiling the table ways, by flooding or by pressure; the flanges at sides of ways form an oil well and are of sufficient height to allow a head of 2 inches of oil above surface of bearing at all times. (It may be of interest to know that 32 gallons of oil are required for this purpose.)

There are two sets of oil channels, one consisting of a number of grooves ½ inch wide by ½ inch deep, running diagonally across the ways, in opposite directions (open at the ends) sub-dividing the same into a number of triangular faces, free circulation being thus induced from side to side of bearing.

The pressure system consists of a number of pipes from pressure main terminating in radial oil grooves in ways.

5. The pressure and return piping being of brass, all branches are bent, no elbows being used. Two mains extend entirely around bed plate, as seen in vertical section of mill, the lower being the pressure and upper the return mains. Six 1-inch branches from return main pass up through oil well at side of ways and terminate in open pipes 2 inches high, to take care of surplus oil. All other bearings are piped to a central location and are fitted with sight-feed oil cups.

Table.

6. The table is 20 feet 4 inches in diameter, and is made in three sections, each section weighs 26,300 pounds—total weight of table 78,900 pounds.

The table has a range of speeds from one revolution in 8 minutes to one revolution in 1 minute. The greatest gear reduction obtained for driving table being 1,040 to one.

Table is driven through a spur gear 20 feet pitch diameter, 3.1416 inches circumferential pitch 10½ inches face, made in two pieces of gun iron, bolted to under side of table, Fig. 276. This gear weighs 14,000 pounds and is driven by two pinions, 180 degrees apart. Pinions are 15 pitch diameter, and are made of forged steel.

7. The spindle for the table has a length of 6 feet 9 inches, and greatest diameter 5 feet 6 inches where it rests in inner way of bed plate, and has a taper of ¾ inch per foot on main bearing, being 46 inches diameter at large end and 40 inches long; weight of same being 10,100 pounds. It is also bored out and splined at each end to receive bearings for the boring bar sleeve, and

also adjustments for the same. Bearing for table spindle is 48 inches outside diameter, 40 inches long, has babbitted pockets on inside for spindle bearing, Fig. 277, bored to a diameter of 46 inches at large end with $\frac{3}{4}$-inch taper per foot, and

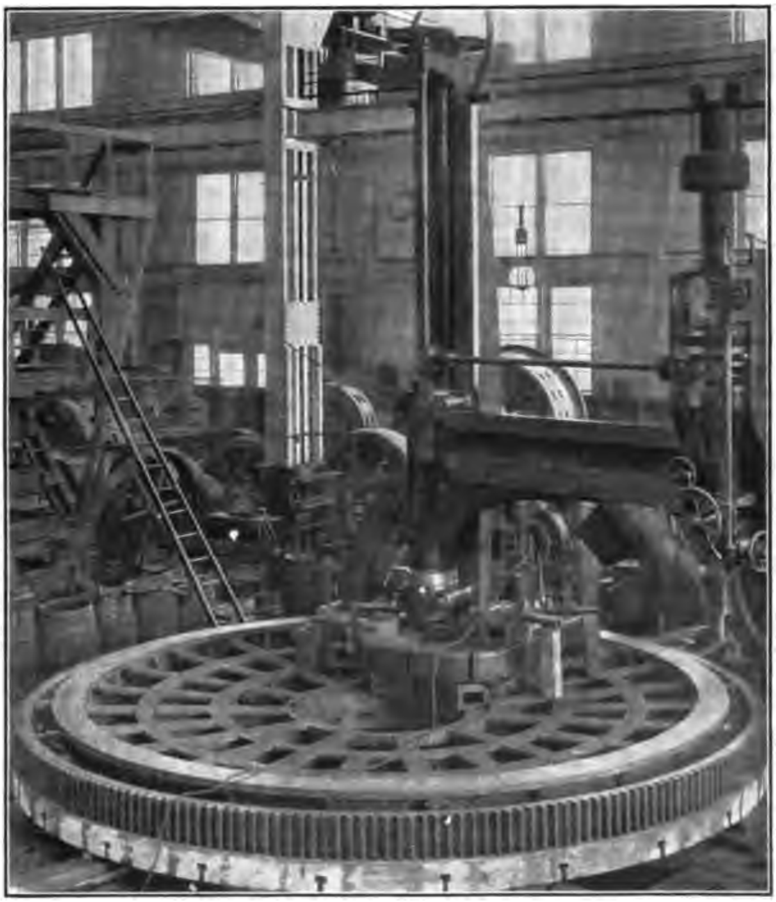


FIG. 276.

is adjusted by means of set screws in a ring, which is bolted to under side of bed plate, one-half of the screws being arranged to push bearing upward, and other half to draw down. This bearing weighs 3,700 pounds. Immediately outside of revolving table there are 14 floor plates, making a stationary table of 44 feet diameter, each plate weighing 19,000 pounds, making a total of 266,000 pounds. Outside of this table there extends 15

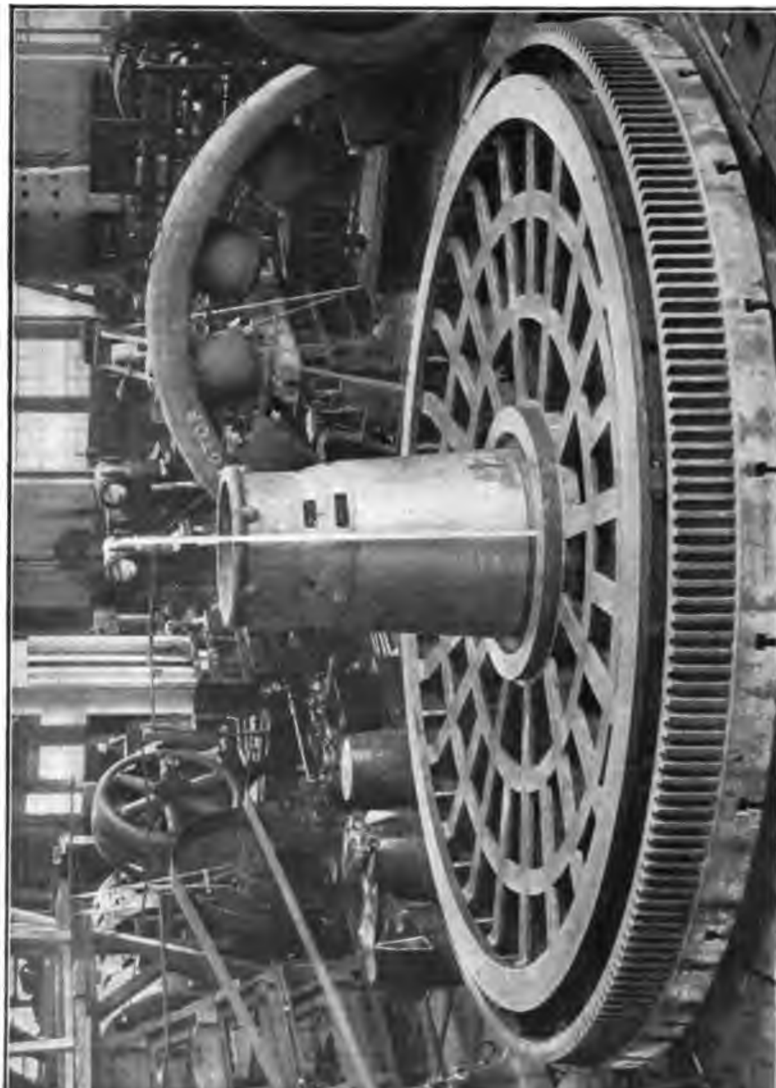


Fig. 277.

plates radially 6 feet wide by 10 feet 6 inches long, making complete outside diameter of 65 feet. Each of these plates weigh 13,000 pounds, making a total weight for the 15 of 195,000 pounds.

8. The stationary table has two tracks upon its surface, centre of inside track being 30 feet diameter and centre of outside track 40 feet diameter, both 12 inches wide. The object of these tracks is to form an outer bearing for support on which boring tool heads rest when boring out large fly-wheels or frames, or forming outer bearing for frames or fly-wheels when they are being revolved by table and are being turned on their outside diameters. These tracks are covered by a moving platform, to protect them from chips or dirt, and upon which the operator may stand.

Boring Bar.

9. The bar support, Fig. 278, consists of a cast iron shell made up of a number of segments which have been machined up and bolted together, and is suspended from under side of bed plate. At *A* is shown a seat for bevel pinion on main table driving shaft; at *B* seats for bearings of diagonal shafts; at *C* seats for main driving shaft of boring bar; and at *D* a seat for step bearing of bar drive, while at bottom is support for boring bar.

10. The boring bar was designed for boring out work varying from 1 foot to 8 feet in diameter, is 24 inches diameter by 16 feet long, and is made to revolve in either direction by means of suitable gearing and reversing clutches through a gear 69½ inches diameter by 6 inches face, which is placed upon the lower end of the bar sleeve. This sleeve, which weighs 8,450 pounds, is 8 feet 1½ inches long, rests and revolves in flat bearing in the top of the table spindle, and is centred by means of the tapered bearings *A* and *B* placed respectively at the top and bottom of the main spindle, keyed to the same to prevent turning, but adjustable—vertically—by suitable adjusting screws, as shown in vertical section of mill. This sleeve has feathers fastened in the bore, through which the bar passes.

11. The bar which is to have an hydraulic feed is made in two sections—each a cylinder—the upper 12 inches diameter by 4 feet 8 inches travel, and the lower 18 inches, bushed with copper sleeve to 17½ inches diameter, and has a travel of 8 feet. The

piston of lower cylinder is stationary and mounted securely upon a hollow piston rod, which contains an internal tube which passes up through the piston to upper end of cylinder, oil for

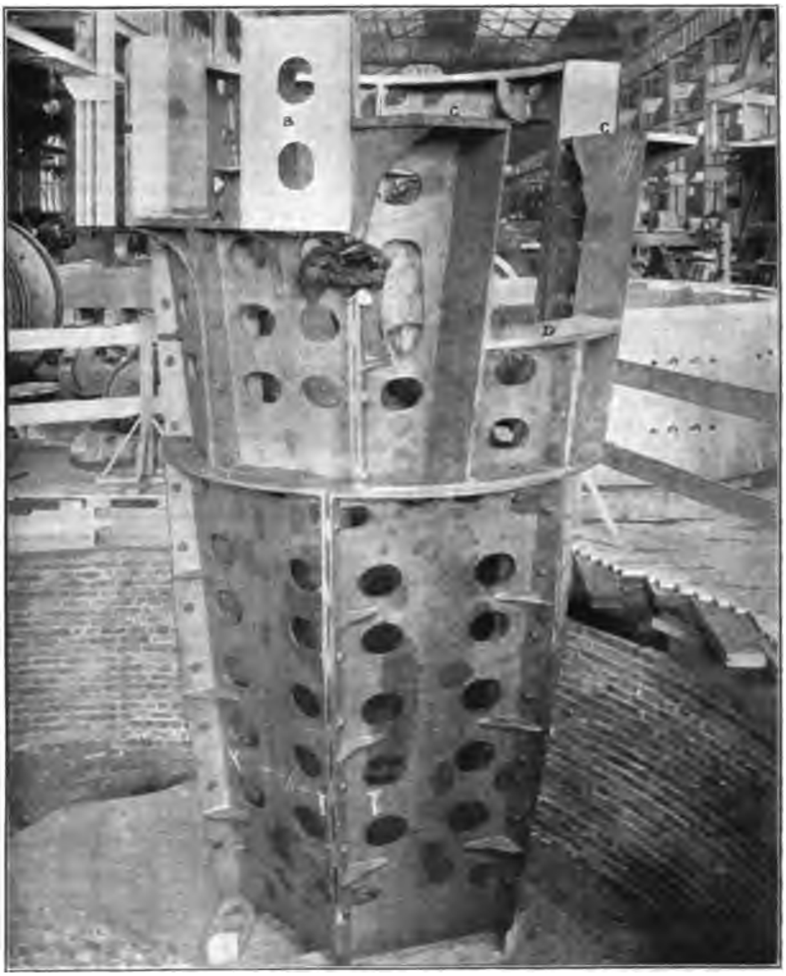


FIG. 278.

upper end passing through this tube and for lower end through outside or piston rod tube and by means of port in the same near its connection with the piston passes into cylinder; thus, by admitting oil to under side of piston, the bar or cylinder moves downward and admission to upper side gives motion upward.

12. Should it be necessary to bore out a piece of work 24

inches or less in diameter, resource is then had to the upper cylinder, where we have a double-acting piston, the rod of which is 8 inches diameter ana forms the boring bar. Oil for operating this plunger is obtained as follows: Valve *A* in bottom cylinder head is opened, the oil passes through valve up through pipe which is embedded in side of bar, up to and through inner head between upper and lower cylinders, thence to under side of top piston; the feed being controlled by the quantity of oil allowed to escape from upper side of piston. It will thus be seen that pressure is on both sides of both pistons at the same time, the pressure from pump being at the lower side of top piston and lower side of bottom piston, while the exhaust is on opposite side of pistons; this is to prevent any jumping effect of the bars in vertical direction when blow holes or other obstructions are encountered. By reversing the main operating valve, feed in opposite direction is obtained, the top of large bar and small plunger being made with taper sockets and key to carry boring heads. These boring heads being provided with suitable cross-feed slides to bore to diameter required. Thus when key-ways are required, the same may be done by removing the boring tools and substituting slotting tools, and then by manipulating the main operating valve the bar may be given the cutting speed required and also have a quick return.

Standards or Housings.

13. The housings are constructed entirely different from the standard type of vertical boring mill. There are two large portable uprights 15 feet high, having one part of upright standing in same line as cross rail and the other standing at right angles thereto, both forming part of common base 9 feet square and tied together on inside near the top by a very strong brace. The arm or cross rail, Fig. 279, which has a vertical adjustment on standards, has bearings and gibs between rail and housings of ample width and length to secure alignment of the same. They also have a large bracket at the back which sildes upon back column of standard and a clamping device at end of rail, which passes across the face of housing, both of which when secured serve to prevent springing of the rail during operation. Additional support is given to rails where they join at the centre, by means of a stationary stand and bracket extending out to and against the

rail, as shown in plan of mill, these rails being of sufficient length to enable a minimum diameter of 12 inches and a maximum diameter of 28 feet being bored and turned without moving the housings.

14. The design of cross rail is peculiar in construction in having the lower face project 3½ inches beyond the upper part; this lower is 12 inches wide vertically and forms the main horizontal guide for saddle, one advantage being a double bearing to sustain the weight, the principal object being, however, greater

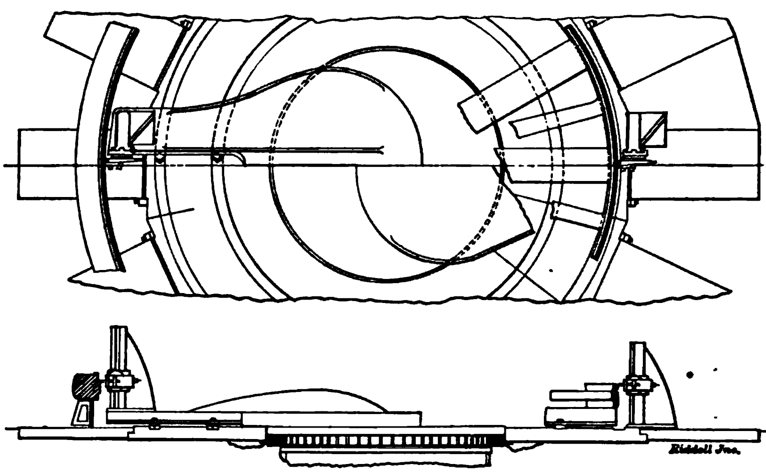


FIG. 279.

accuracy and less liability for the saddle to oscillate, owing to the proportions of length to width of bearing, which is 12 x 42 inches. The usual proportions of large boring mill saddles being about square. We still retain the great width of rail to counteract the tool action.

15. Movement or feed of saddles along the rail is made by means of hydraulic mechanism, the piston and rod being stationary and attached to bracket on outer end of rail. The cylinder is allowed to float, carrying on inner end a pair of gears proportioned two to one, which engages in two racks, the upper or stationary rack meshing with small gear, and the lower racks attached to saddle and meshing with large gear; this arrangement gives a motion of head equal to three times that of cylinder, pressure being admitted and discharged in the same manner as described in main boring bar.

16. The boring bar in tool heads—12 inches diameter by 15 feet long—are held in bearings on swivel plate, as on standard type of mill. This bar is bored out and fitted with a double-acting piston and hollow piston rod and cross head to which are attached two racks which serve as keys to prevent turning of bar and also for raising or lowering of bar or tool heads. The bar can be held in position as in standard mills, or can be lowered

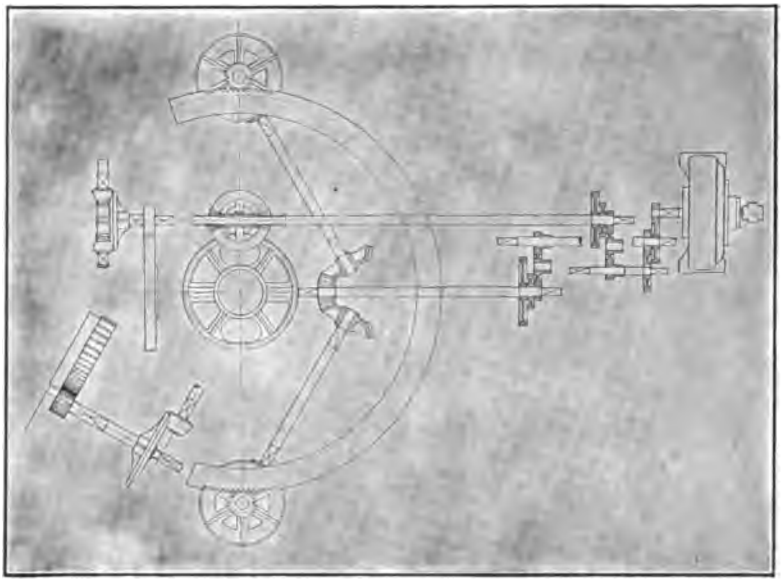


FIG. 280.

and clamped to floor when turning a piece of work. (See vertical section of boring mill, left-hand bar.)

17. The tool head is also provided with suitable device for raising or lowering bar by hand.

The tool head on bar consists of a cross-slide and swivel attachment, capable of being revolved around the bar by means of worm and wheel, and moved vertically along the bar by means of the two racks above mentioned.

18. The housings are supported by the stationary table and floor plates extending from the table to a diameter of 65 feet, being free to travel from a position close to table to outside diameter of plates, in which position they are capable of boring or turning work of a maximum diameter of 60 feet.

Housing-rails, etc., weighing 155,580 pounds.

Fig. 281.

19. The power for driving this mill is obtained from a 50 horse-power variable speed motor. This motor has a range of speeds of from 128 to 512 revolutions per minute inclusive, power being transmitted from pinion on armature shaft through train of gears to main driving shaft; Fig. 280, upon main driving shaft is bevel pinion which meshes into two bevel gears on two shafts placed diagonally, upon other end of which are two bevel pinions meshing in two large bevel gears, mounted upon vertical shafts, upon which are the two pinions for driving table gear. Motor is controlled by means of a portable controller, which can be carried to any point about the mill convenient for the operator. Fig. 281 shows the machine applied to boring a field ring 34 feet in diameter.

Net total weight of boring mill complete is 885,620 pounds.

No. 1001.*

THE MACHINE SHOP PROBLEM.†

BY CHARLES DAY, NICETOWN, PHILADELPHIA.
(Junior Member of the Society.)

1. It has been our good fortune to have had the opportunity to familiarize ourselves with Mr. Fred W. Taylor's work in shop management, as well as the paper which he has prepared for this meeting. Being heartily in sympathy with his methods, at the present time being engaged in the introduction of his system for one of our clients, it will hardly be necessary to state that many of the factors considered below are original with him.

It is not the intention, however, of this paper to either discuss or outline the Taylor System, but rather to point out a few facts which have been forcibly impressed upon us when in charge of the equipment and management of manufacturing establishments. Foremost among these we would mention the absence of a uniform development of the various departments of which they are composed.

2. Starting with the broadest possible subdivision of a business, we usually find a marked contrast in the general efficiency of the departments; the management, as a rule, directing the greater part of their time and energy to the development of lines for which they have a particular taste, according as they may have been influenced by their past opportunity and experience. This

---

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV., of the *Transactions*.

† For further discussion on this topic consult *Transactions* as follows:

No. 341, vol. x., p. 600: "Gains Sharing." H. R. Towne.
No. 449, vol. xii., p. 755: "Premium Plan." F. A. Halsey.
No. 647, vol. xvi., p. 856: "Piece Rate System." F. W. Taylor.
No. 909, vol. xvii., p. 1040: "Drawing Room and Shop System." F. O. Ball.
No. 928, vol. xxiii., p. 341: "Bonus System for Rewarding Labor." H. L. Gantt.
No. 965, vol. xxiv., p. 250: "Gift Proposition for Paying Workmen." Frank Richards.

state of affairs is as clearly exemplified when planning the equipment and organization of a new plant as the maintenance and development of an old one.

The buildings, which should be secondary to the equipment, are commonly designed and erected without proper consideration of the work in view, limitations being imposed by this work rendering the use of the proper methods and apparatus of but small value. The shop architect cannot lay out, to advantage, buildings for a given plant unless conversant with the character of the work. The location of the machines, the system of power transmission and innumerable other details materially affect the design of buildings. Notwithstanding these almost self-evident facts, manufacturers continue to design and erect their buildings independently of the equipment or the work in view. So much can be effected by a proper consideration of all details in connection with the plant before proceeding with any work, that we will take this problem up more fully later on.

Equally one-sided conditions are encountered in the establishment that is in operation, a most efficient sales department existing alongside a shop where economic production is out of the question; and so examples could be cited indefinitely.

A further analysis of any one department usually reveals the same state of affairs, a lack of coördination and thoroughness being exemplified. The success of one plant, as compared with another engaged in the same line of work, depends upon the balance of the efficient and inefficient departments, and just as Mr. Taylor has pointed out that a machine shop foreman possessing all the qualities required by that position can but rarely be obtained, so the majority of establishments excel in but a few of the branches of which their business is composed.

Needless to say there is seldom any premeditated desire to develop one side of a business at the sacrifice of the other, lack of appreciation of the relative importance of the different factors being the chief reason for error in this direction. To be successful in this work requires a rare combination of the ability to stand off and "size up" the problem as a whole, followed by a concentration of energy on the details which alone can culminate in the anticipated results.

3. It is for this reason that an engineer making a study of this work can frequently detect the weak points of a manufacturing plant, the system of fundamental analysis being more powerful in

the hands of one who has not been in close association with the work. We think the condition of affairs can hardly be illustrated better than by quoting from an editorial in one of our technical papers of about a year ago, which stated that "many engineers suffer from using lenses of too high power and too narrow a field; in such matters the telescope is sometimes of as much value as the microscope. It often pays better to learn what others are doing than to know with unnecessary particularity what one is doing one's self."

While no two establishments are alike in detail, the same course of study should be pursued in every instance. A comprehensive understanding of any problem can only result after a most exhaustive study of the smallest details into which it can be subdivided, such investigation, if properly carried out, invariably resulting in an insight that is truly astonishing.

4. We have found that the graphical presentation of complex problems facilitates greatly a study of their various elements, this scheme being resorted to by us in many lines of work. While in many cases only "relations" can be expressed in this way, the mind can grasp the problem, as a whole, so much more quickly, the system is invaluable.

While we intend to devote this paper to the machine shop in particular, a general subdivision of the departments of a given establishment is given below (Fig. 282), showing the position occupied by the machine shop in the general scheme.

5. No one man would attempt to have sole charge of all the detail work in all of the departments enumerated, the subdivision of a business among a number of heads being a natural course to follow. At the same time some means must be provided for bringing all the departments in touch with each other in such a way that they will coöperate and direct all their efforts to a common end with the least expenditure of energy. A lack of coöperation, in the full sense of the word, between the principal subdivisions of a business, results in an enormous expenditure of useless energy and money in the majority of manufacturing establishments. All that may be said in this connection, when considering the most general subdivisions of a business, is equally true when discussing the relations of the subdivisions of elements of each department.

Antagonism between the sales and engineering departments prevents the latter from embodying changes or alterations in their

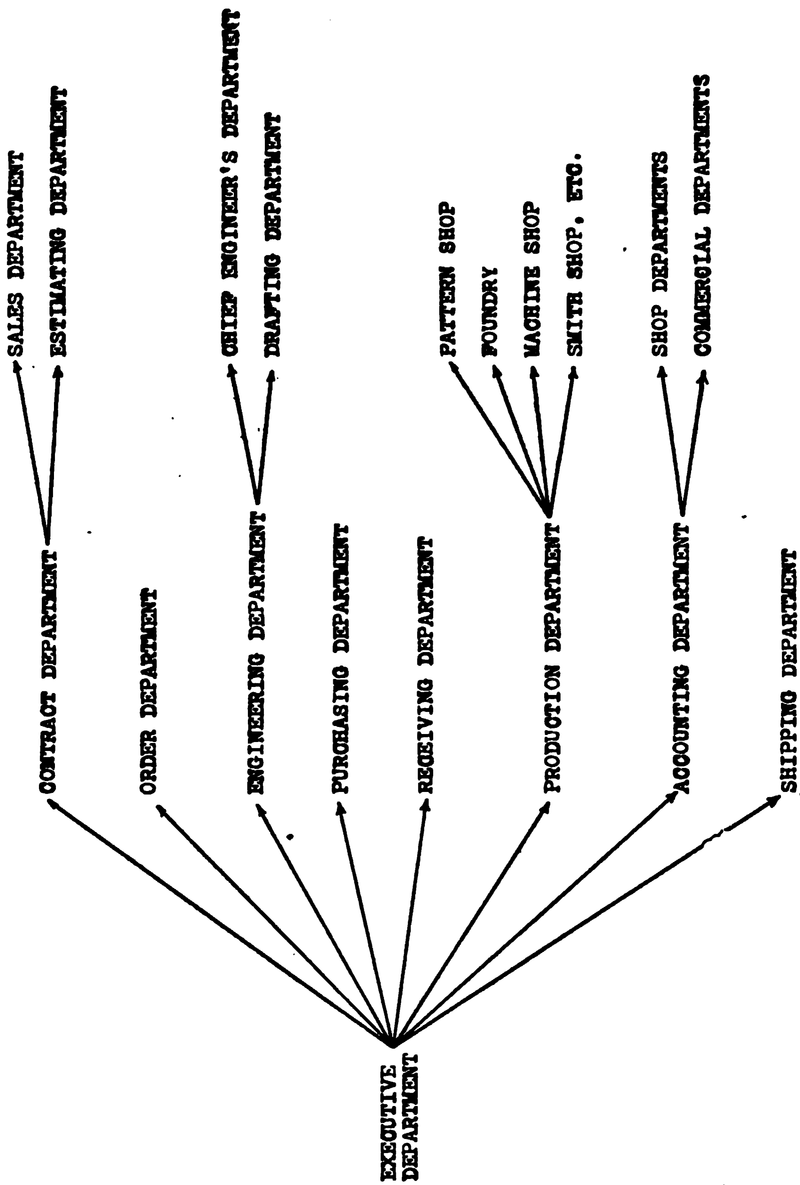

EXECUTIVE DEPARTMENT
CONTRACT DEPARTMENT
SALES DEPARTMENT
ESTIMATING DEPARTMENT
ORDER DEPARTMENT
ENGINEERING DEPARTMENT
CHIEF ENGINEER'S DEPARTMENT
DRAFTING DEPARTMENT
PURCHASING DEPARTMENT
RECEIVING DEPARTMENT
PRODUCTION DEPARTMENT
PATTERN SHOP
FOUNDRY
MACHINE SHOP
SMITH SHOP, ETC.
ACCOUNTING DEPARTMENT
SHOP DEPARTMENTS
COMMERCIAL DEPARTMENTS
SHIPPING DEPARTMENT

Fig. 282.

apparatus which might make it much more efficient and suitable for the conditions which it is to meet.

The Drafting Room, through their ignorance of the shop equipment, constantly design apparatus which can only be machined at great expense. The Pattern Shop, for the same reason, could frequently greatly simplify the work in the shop by helpful construction of patterns which would facilitate handling, centering, etc., and so examples could be cited indefinitely illustrating the point made above.

6. When a shop is in operation these conditions can be met to the best advantage by periodic meetings between the heads of the various departments, where every man has full privilege to the floor and every question which is raised is definitely decided and, if approved, put in force immediately. In this way, every question, even of the most trivial character, is brought before a number of men and its value quickly determined. Nothing is more discouraging to an enthusiastic worker than to have schemes, which he has formulated after much thought and experiment, passed upon as good but not put into operation, the man who has the power postponing it indefinitely on account of other work which he may have in view.

7. Conditions are, of course, very different in different establishments. In the "tonnage" plant one man may be able to take care of all the work, carrying in his mind the entire scheme and, if he has exceptional ability in this particular field, efficient results are likely to follow. When the work is complex in character, however, it must be subdivided among a number of men, it being ever borne in mind that the first essential to success is thorough coöperation between the various departments.

8. Devoting our attention to the Production Department, we still find the subject too complex to consider intelligently without a chart giving a further division of the various factors. The chart shown in Fig. 283 subdivides the Production Department into the buildings, equipment, etc., each of these details being further analyzed. The absurdity of spending a large amount of time and energy on any one of these details, without consideration of the others, is self-evident when presented in this way.

9. Reference was made to the importance of proper buildings in connection with manufacturing plants, and, for some lines of work, maximum efficiency can only follow when they have been designed for the work in view, the question being one

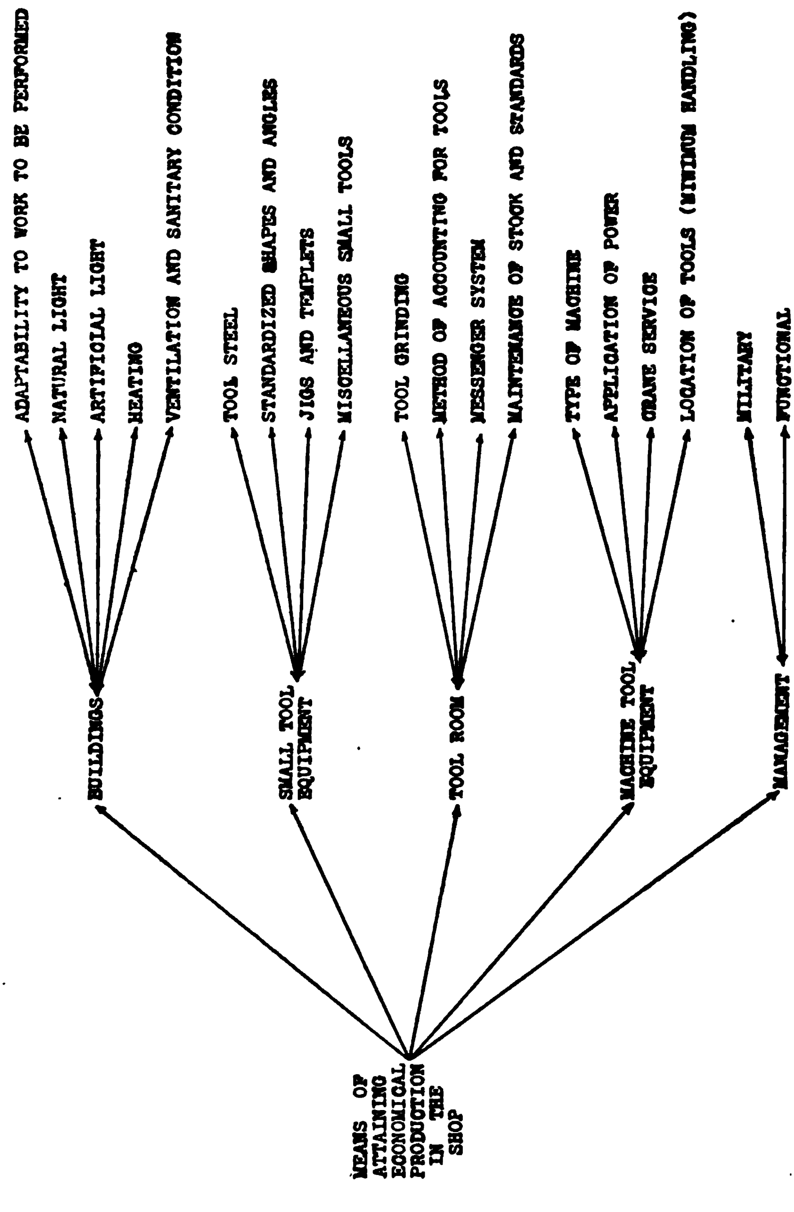

MEANS OF ATTAINING ECONOMICAL PRODUCTION IN THE SHOP
BUILDINGS
ADAPTABILITY TO WORK TO BE PERFORMED
NATURAL LIGHT
ARTIFICIAL LIGHT
HEATING
VENTILATION AND SANITARY CONDITION
SMALL TOOL EQUIPMENT
TOOL STEEL
STANDARDIZED SHAPES AND ANGLES
JIGS AND TEMPLETS
MISCELLANEOUS SMALL TOOLS
TOOL ROOM
TOOL GRINDING
METHOD OF ACCOUNTING FOR TOOLS
MESSENGER SYSTEM
MAINTENANCE OF STOCK AND STANDARDS
MACHINE TOOL EQUIPMENT
TYPE OF MACHINE
APPLICATION OF POWER
CRANE SERVICE
LOCATION OF TOOLS (MINIMUM HANDLING)
MANAGEMENT
MILITARY
FUNCTIONAL

Fig. 283.

of shop requirements and not architecture as ordinarily understood.

Probably nothing has increased the possibilities of the machine shop to a greater degree than the power crane, and although the designer of the building is always informed, in a general way, as to the crane service that will be required, this detail is not usually given nearly sufficient consideration. To properly cover the floor space with power cranes, jib cranes, etc., requires a most careful study of the location of various machines, which, in turn, necessitates a thorough understanding of the work in view.

Old systems of management, as a rule, take no adequate account of the progress of the various pieces of work through the shop, but when operations are analyzed and prescribed, as by the Taylor System, the route of each piece must be carefully planned.

The customary scheme of allotting separate sections of the side bays of a shop to different classes of work, such as Lathe Department, Drill Press Department, Grinding Department, etc., and allowing sufficient additional space to take care of the growth of these departments, can hardly be termed good practice. Money is tied up for a number of years, which yields no return; and when the space is ultimately occupied, further extensions usually result in a most inefficient arrangement of tools.

The designs of a number of the largest shops which have been erected during the past few years consist in erecting shops with perpendicular wings, where the detail work is done. We have but one plant in mind where this scheme has been carried still further, each department being contained in a wing building, which may be extended as the work demands.

The scheme of power transmission adopted will influence quite appreciably the design of buildings, the advantage of using motors on individual machines being frequently justified by the reduced first cost of buildings alone.

10. The lighting of the machine-shop or foundry to a marked extent influences the efficiency of the men, and the importance of this fact is generally appreciated at this time. It is practically impossible to obtain too much light, provided the direct rays of the sun do not fall on the work. As large establishments usually run night and day, a liberal amount of artificial light is also necessary if the different shifts are to turn out equal amounts of work. Shops that are illuminated in a general way by arc lamps

(as well as incandescent lights for detail work) seldom complain of the inefficiency of the night shift.

11. We have pointed out a few of the details which should be borne in mind when planning a new building for a given kind of work. We may appear to dwell at unnecessary length upon details which are self-evident, but we have so frequently been called upon for advice, after limitations had already been imposed by the work which had been completed, rendering the use of various types of desirable apparatus practically impossible, that we do not hesitate to dwell upon it here.

12. The machine-tool equipment must receive the closest study of one familiar with the latest types of apparatus, rapid progression in its development handicapping greatly shops which were equipped but a few years ago.

13. Reviewing, briefly, past conditions in the majority of shops —and in fact many of to-day—we cannot fail to be impressed by the slipshod methods in use on all hands. Purchase of equipment was left almost invariably to a purchasing agent who was in no way conversant with the requirements of machines to be bought, price being his only means of comparison. The fact that such a condition of affairs was allowed to exist was sufficient proof that those in charge of the shop were scarcely more capable to judge of the earning power of the apparatus than he.

Some of the largest shops used a cheap grade of carbon steel for cutting tools, instead of the "air-hardening" variety which would permit of double the cutting speed, the reduced first cost being their reason for this policy. In such a plant five thousand dollars ($5,000) invested in tool steel might readily effect a saving on the labor bill of fifteen thousand dollars ($15,000) annually. Such an illustration exemplifies forcibly the absence of scientific thought and investigation existing but a few years since.

14. The "type of equipment" will depend upon the character of the work, and, as the province of the machine shop is radically different for various lines of work, there are no hard-and-fast rules which may be followed. The three examples given below will illustrate this point:

(1) In a rolling mill plant, for example, the repair-shop equipment is only used in case of break-downs, and in a number of instances we can recall special machines which have been purchased for repairing single details of the equipment and which have been used but a few days in several years. This illustrates

an extreme case, where it is necessary to carry a heavy investment in order to be prepared for break-downs. The equipment or management of such a shop would not influence greatly the cost of the product; consequently, when purchasing machines to meet these conditions, the consideration of many of the details which would prove most efficient, were the tools to operate at all times, would not be desirable.

(2) The work in a locomotive shop consists largely in overhauling engines at periodic intervals, so that, under normal conditions, these shops should operate at their full capacity. Special machinery can be used for a great deal of this work. In this instance the shop is a much more important factor in the general scheme, the periodic repair of the rolling stock being a first essential in railroad work. Economic production in this field results when the locomotives and cars are detained in the shop the least possible time, the actual saving in machinists' wages being a small item as compared with the earning power of the rolling stock.

(3) On the other hand, the equipment and management of a machine shop doing purely manufacturing work are vital factors of the organization, a slight reduction in labor cost frequently resulting in an enormous increase in business. This is particularly true of concerns manufacturing duplicate articles in large quantities, where price materially effects the quantity of goods sold. High efficiency usually accompanies duplication, but the only way that a low first cost may be attained, when doing work which varies in character, is by dictating to the workmen the methods of machining as described in connection with the Taylor System of Management.

15. It matters little whether we turn our attention to the equipment or management. The same conditions are met, and such statements as would indicate that superior management of an organization offsets an inefficient equipment should be accepted reservedly. They are so closely related that a thorough understanding of one is not possible without knowledge of the other.

Why has shop equipment advanced so slowly aud why so much doubt as to the merit of recent discoveries, such as the high-speed tool steel and the motor drive? Simply because shop management —the vital force behind the machine—has been unable to keep pace with the development of the apparatus, the lack of it constantly acting as a drag on pioneering work in this direction.

Do any of the well-known schemes of management, as ordinarily interpreted, with the exception of the Taylor System, involve any understanding as to the fundamental principles underlying the art of machining? Individual concerns that have developed machines possessing many refinements over those made by competitors, have found but small incentive to market such tools, prospective purchasers having neither the knowledge to appreciate or take advantage of their possibilities in the shop.

16. The efficiency of machine-shop equipment should be judged only from its ability to produce the desired result at a minimum cost, and this, in turn, is governed as much by the information at the disposal of the operators as the machines themselves. In an extreme case, such as a full automatic screw machine, we might suppose that the ability of the designer would assure the success of the tool; but even in this case innumerable details arise, such as the grinding and setting of cutters, the delivery of stock to and from the machine, etc., which may or may not be efficiently taken care of by the purchaser.

Turning to the other extreme—an engine lathe doing a general class of work—we find the workman confronted by innumerable problems governing economical production, which he (and in many cases his superiors) fails to recognize. For example, the proper cutting speeds for different materials and different cuts; the relative advantage of a heavy cut and slow speed, or a light cut and fast speed; and the capabilities of the machine. These are but a few of the details. Such information can only be obtained from experimental work carried on along scientific lines; and as long as schemes of management take no cognizance of this data, the introduction of modern tool steels, the motor drive, etc., will necessarily be slow; consequently, we cannot discuss the merits of various types of apparatus, unless conversant with the problems of organization and management. The absence of this knowledge leads many engineers to most erroneous conclusions.

17. At a recent meeting of the Philadelphia Engineers' Club, Admiral Melville pointed out forcibly the great need of experimental research in all lines of engineering. He cited the laboratory which the German Government have instituted at Charlottenburg and said that the data collected from experiments conducted here unquestionably accounted for Germany's undisputed position as the foremost designer and builder of battle-ships and "ocean greyhounds."

In certain directions a great deal of information has been obtained and tabulated, without which the present-day engineer would make but slow progress. Since the exhaustive experiments on tensile strength of steel and wrought iron, by David Kirkaldy in 1858, the most exact data has been accumulated, so that a structural building or bridge, for example, can be designed for given conditions with an accuracy inconceivable a few years ago.

18. Is the machine tool designed with this accuracy, or have the builders of such apparatus any truly intelligent ideas as to its capabilities? In the large majority of cases, No! When we look back and see the rich results invariably following careful investigation and research, it seems strange, indeed, that so few manufacturers are alive to their value.

A better example of the above principles could not be cited than the development of tool steel—the starting-point for all investigation relative to the machine shop.

19. The work of Benjamin Huntsman, over 160 years ago, who labored for years before producing a high grade of crucible steel, which at once took the place of steel made by the "cementing process," marked an epoch in industrial development. Hardly less noteworthy is the work of Heath and Mushet who, by the addition of manganese and tungsten, produced an "air-hardening" steel, which held its own until the discovery of the Taylor-White process a few years ago.

It is significant to recall that the pioneering work has not been done by the manufacturers. Huntsman was a watchmaker, whose study of the steel industry was prompted by the poor character of his clock springs; Mushet, an accountant at the Clyde Iron Works; Taylor and White, engineer and metallurgist, respectively, in no way associated with the manufacture of tool steel, but intent on obtaining a cutting-tool of uniformity and high efficiency.

20. The best efforts of the engineer can only be called forth by a thorough realization of the need and utility of certain improvements. It is unfortunate that the manufacturer, in many instances, is not in close enough touch with the conditions he is endeavoring to meet to attain the best result. Many of the builders of electrical apparatus suffer from this cause, designing and manufacturing equipment for machine-tool driving which may be most efficient from the standpoint of the electrical engineer, but utterly unsuited to shop requirements.

21. In contrast to the methods described above, we must again allude to the work of Mr. Taylor in the field of shop equipment and management. His system of management consists primarily in a Planning Department which collects the necessary information as to the exact methods of doing the work and imparts it to the workmen through the medium of a system of Functional Foremanship. This Planning Department bears the same relation to the shop that the Draughting Room does to the Engineering Department. This statement conveys no impression as to the vast amount of detail knowledge Mr. Taylor has accumulated and which accounts largely for his success. His methods have constantly aimed at uniformity and standardization, the Taylor-White process being but one of many examples which could be cited as the result of this work. Together with his assistants, he has obtained an enormous amount of data relative to cutting metals, which is made applicable by means of slide rules. The underlying principle of all his work—a high wage with a low labor cost—involves the keenest appreciation of the labor problem. Not a single detail of shop equipment can escape the application of the Taylor system, and it is only in this way that continued high efficiency of operation can be secured.

22. Returning to the small-tool equipment, a separate paper could readily be written on each of the subdivisions enumerated on Fig. 283.

The small attention given to the cutting-tool in the vast majority of shops is astonishing when we realize how directly the time of machining is dependent on the character of the steel. We are all constantly hearing of phenomenal cutting-speeds, etc., but it is the efficiency of the tools in the tool racks that is a gauge of their value. If these tools are not forged and ground to standard angles and reground by a man who realizes fully the care which must be exercised in this work, the chances are that the majority of them will be but scarcely better than the original Mushet steel.

In the majority of shops the possibilities of the equipment are cut in two by lack of attention to the belting and cutting-tools. Notwithstanding the forcible way Mr. Taylor has frequently pointed out the need of proper care of belts, few shops give them any consideration.

The "Method of Accounting for Tools," "Messenger System" and "Maintenance of Stock and Standards" are details which can only be considered in connection with a given plant.

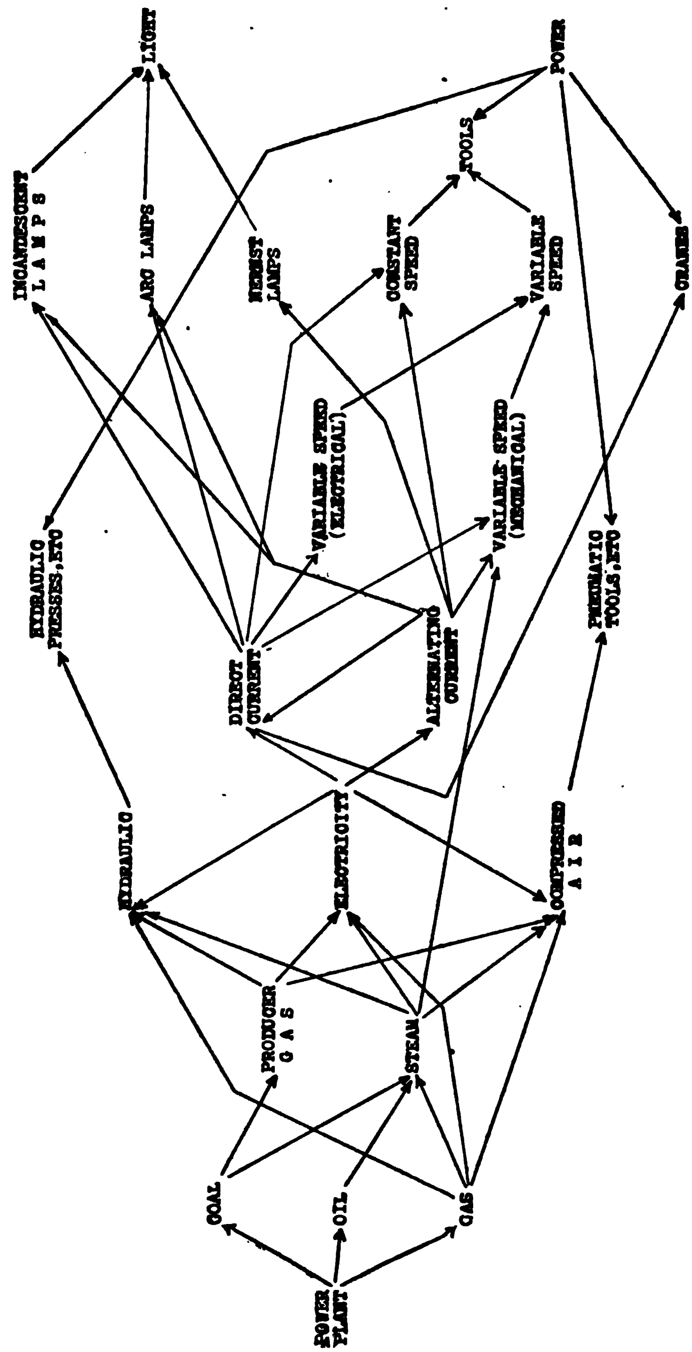

LIGHT
POWER
TOOLS
INCANDESCENT LAMPS
ARC LAMPS
NERNST LAMPS
CONSTANT SPEED
VARIABLE SPEED
CRANES
VARIABLE SPEED (ELECTRICAL)
VARIABLE SPEED (MECHANICAL)
HYDRAULIC PRESSES, ETC
DIRECT CURRENT
ALTERNATING CURRENT
PNEUMATIC TOOLS, ETC
HYDRAULIC
ELECTRICITY
COMPRESSED AIR
PRODUCER GAS
STEAM
COAL
OIL
GAS
POWER PLANT

Fig. 284.

23. When deciding upon the type of machine desirable, it is necessary to consider the question of "power application," but as this, in turn, may depend upon other considerations—such as transmission, lighting, etc—it is desirable to apply the same scheme of graphical analysis.

Fig. 284 indicates approximately the number of courses which may be open for fulfilling the conditions in view. Either coal, oil or gas may be used, according to the location and size of plant, and so the desirability of each of the alternatives following will be governed by special conditions.

24. Probably no subject has been open to more energetic discussion than that of the motor-driving of machine tools. The mistake many authors have made when writing on this topic is that while their experience has been in but one line of work they apply their deductions to machine shops in general. A system of driving which might be most desirable for a shop manufacturing a great variety of articles would not, in all probability, be suited for a railroad repair-shop.

The possible advantages resulting from the use of individual motors and the various types of apparatus manufactured for this work are graphically shown in Fig. 285. The names of concerns who have installed the different systems are given to the right. During the past five years a discussion of these systems has received a great deal of consideration before this and other engineering bodies, and we will only say, in this connection, that the question is one of shop requirements rather than electrical design.

If a plant covers a large tract of land, and the variable-speed machines require but a small percentage of power, it might be desirable to generate alternating current for lighting and constant-speed motors, using a motor generator giving multiple-voltage circuits for the variable-speed tools. Such a plant would be using both alternating and direct current, while in more condensed plants one or the other alone would have decided advantage; and so it is with the numerous systems of motor-driving upon the market at the present time. There are conditions where each may be especially suited.

It is not the intention of this paper to consider, in detail, the schemes of motor-driving. There are, however, a few general conclusions which can be stated which may prove of assistance when considering the question for a given line of work.

If a cutting tool is to work to its maximum efficiency, the cutting

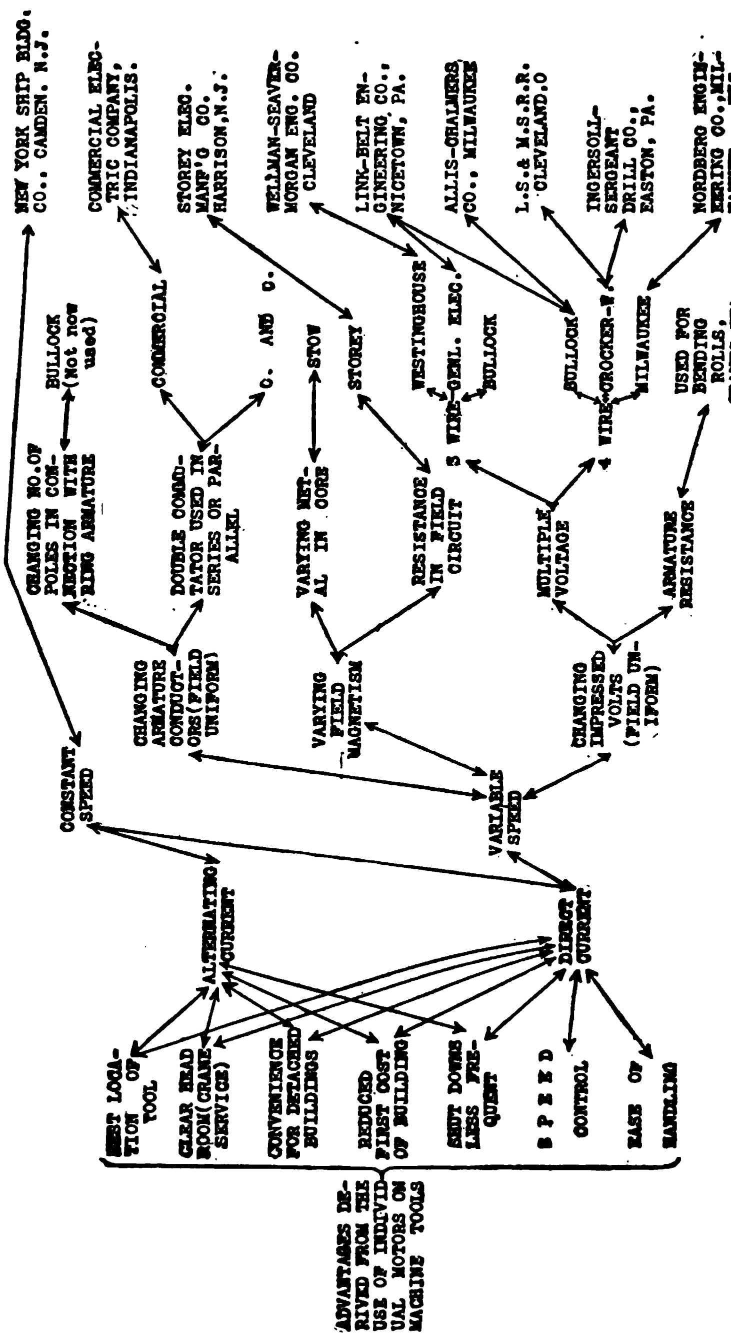

ADVANTAGES DERIVED FROM THE USE OF INDIVIDUAL MOTORS ON MACHINE TOOLS
BEST LOCATION OF TOOL
CLEAR HEAD ROOM (CRANE SERVICE)
CONVENIENCE FOR DETACHED BUILDINGS
REDUCED FIRST COST OF BUILDING
SHUT DOWNS LESS FREQUENT
SPEED CONTROL
EASE OF HANDLING
ALTERNATING CURRENT
DIRECT CURRENT
CONSTANT SPEED
VARIABLE SPEED
CHANGING ARMATURE CONDUCTORS (FIELD UNIFORM)
VARYING FIELD MAGNETISM
CHANGING IMPRESSED VOLTS (FIELD UNIFORM)
CHANGING NO. OF POLES IN CONJUNCTION WITH RING ARMATURE
DOUBLE COMMUTATOR USED IN SERIES OR PARALLEL
VARYING METAL IN CORE
RESISTANCE IN FIELD CIRCUIT
MULTIPLE VOLTAGE
ARMATURE RESISTANCE
BULLOCK (Not now used)
COMMERCIAL
C. AND C.
STOW
STOREY
3 WIRE
WESTINGHOUSE
GENL. ELEC.
BULLOCK
4 WIRE
BULLOCK
CROCKER-W.
MILWAUKEE
USED FOR BENDING ROLLS, CRANES, ETC
NEW YORK SHIP BLDG. CO., CAMDEN, N.J.
COMMERCIAL ELECTRIC COMPANY, INDIANAPOLIS.
STOREY ELEC. MANF'G CO. HARRISON, N.J.
WELLMAN-SEAVER-MORGAN ENG. CO. CLEVELAND
LINK-BELT ENGINEERING CO., NICETOWN, PA.
ALLIS-CHALMERS CO., MILWAUKEE
L.S.& M.S.R.R. CLEVELAND, O
INGERSOLL-SERGEANT DRILL CO., EASTON, PA.
NORDBERG ENGINEERING CO., MILWAUKEE, WIS.

Fig. 285.

speed should be maintained constant for a given depth of cut and a given feed; consequently, some means should be provided for accelerating the spindle speed of a lathe when the tool is working from a larger to a smaller diameter, such as facing cylinder heads, etc. A lathe of this character may be truly termed a variable-speed machine. In the average shop, however, there is very little opportunity for work of this kind, the majority of lathe work consisting of longitudinal cuts. If the lathe operates on but one class of work, the proper spindle speeds and feeds can be obtained, which should not be changed as long as conditions remain unaltered. If, on the other hand, a great variety of work is handled by a lathe, the tool will constantly work on different diameters, variable speed being equally as important in this case as in the first considered, although a uniform increase, as the work proceeds, would not be required. Simple as this classification may seem, the electrical engineer repeatedly fails to see that a system of motor driving that would be applicable in one case utterly fails in another.

Practically all machine shops have some variable-speed tools, and, here again, it is the province of the engineer to determine the relative importance of the various factors. A manufacturer who advertises a variable-speed countershaft or motor for machine-tool driving which will give any speed, shows his ignorance of shop conditions where a refinement of this kind cannot be used to advantage. In fact, after visiting practically all the shops that have installed multiple-voltage equipment offering the possibilities of close-speed regulation and ease of handling, we are convinced that the purchasers are not beginning to realize an adequate return on the investment. A better illustration could not be found of the interdependence of management and equipment.

25. The two principal types of management—military and functional—are of course capable of the same analysis and graphical presentation as illustrated above.

Fig. 286 is included as showing a further subdivision of the departments of Fig. 282.

26. While all the charts given above are only of value in so far as they present to the mind a picture which can be readily comprehended, we can, at times, graphically distribute costs, etc., showing the cost value of the different operations. Such a chart is illustrated in Fig. 287, and indicates in what direction economies are most likely to be effective.

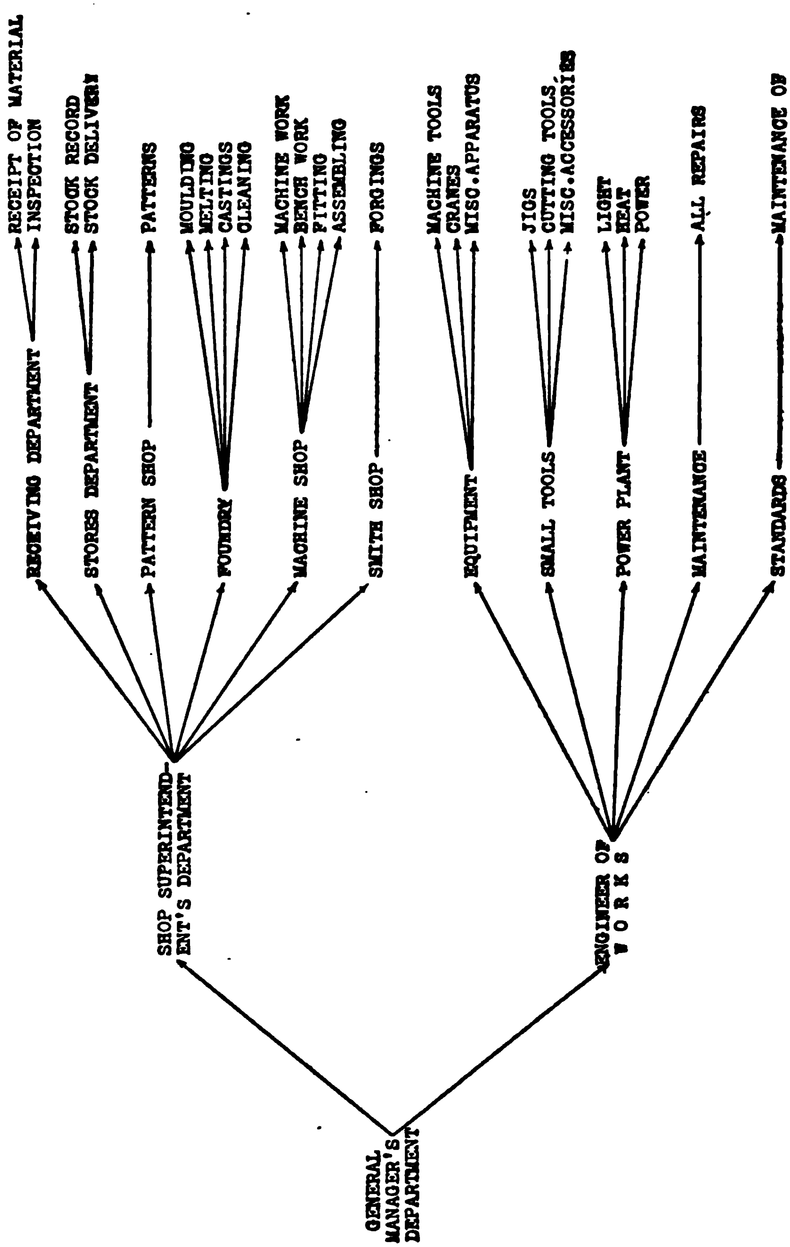

GENERAL MANAGER'S DEPARTMENT
SHOP SUPERINTEND-ENT'S DEPARTMENT
ENGINEER OF WORKS
RECEIVING DEPARTMENT
RECEIPT OF MATERIAL
INSPECTION
STORES DEPARTMENT
STOCK RECORD
STOCK DELIVERY
PATTERN SHOP
PATTERNS
FOUNDRY
MOULDING
MELTING
CASTINGS
CLEANING
MACHINE SHOP
MACHINE WORK
BENCH WORK
FITTING
ASSEMBLING
SMITH SHOP
FORGINGS
EQUIPMENT
MACHINE TOOLS
CRANES
MISC. APPARATUS
SMALL TOOLS
JIGS
CUTTING TOOLS,
MISC. ACCESSORIES
POWER PLANT
LIGHT
HEAT
POWER
MAINTENANCE
ALL REPAIRS
STANDARDS
MAINTENANCE OF

Fig. 286.

27. In conclusion, let us again state that a comprehensive understanding of any problem can only result after an exhaustive study of the smallest details into which it can be subdivided. The success of modern methods in the accounting, as well as the productive departments depends on this.

The balance of accounts of the yearly business will unquestionably reveal the profit or loss, but gives no idea as to how to better conditions. A system of cost keeping—which gives the total cost of the different articles manufactured—may aid greatly in estimating, but will prove of small value as a check on efficient pro-

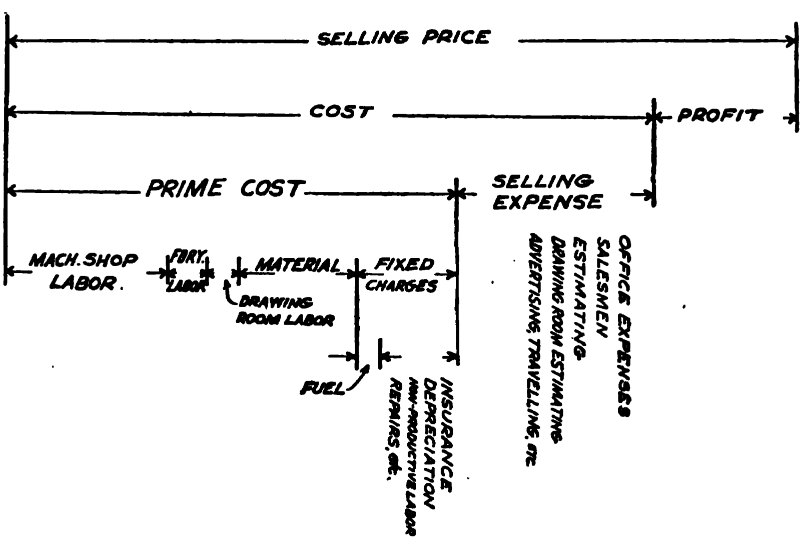


FIG. 287.

duction. A system of cost keeping should not only give the present cost, but indicate how this figure may be lowered. To accomplish this end, each operation must be studied and recorded and each pound of material checked. The system must be alive and full of energy, as mere *form* is nothing.

28. It must not be overlooked that shops that wish to be pioneers must do considerable experimental work, which, in turn, will result in the collection of facts and data to be at the disposal of those who are anxious to follow, the expense incurred being trivial compared with the advantages resulting therefrom. As we stated, however, the concerns that realize to-day the advantages to be derived from such management and organization will

be benefited and will also reap reward in the next industrial depression. There is no standard that is attainable. Shops that lag behind, in order to make sure that each move is thoroughly justified, will arrive at the position occupied to-day by the pioneers only to find that the latter have grasped new principles and still lead in economic production.

DISCUSSION

Mr. F. W. Taylor.—I would call particular attention to the graphic method which Mr. Day has adopted of making clear an exceedingly complicated problem. In my opinion it would require pages of writing to describe what he has very simply expressed by means of diagrams.

Mr. Wm. Kent.—I agree with what Mr Taylor has just said. I have had opportunity to investigate Mr. Day's work, and I can say that it is worth the attention of every member of our profession. I also would concur in what Mr. Taylor said about the fate which befell his paper some eight years ago, and would express my belief that the paper he has brought before the Society now will not be appreciated to-day as much as it deserves, and neither will Mr. Day's paper receive the attention it deserves, and this is true because the members of this Society are too busy to read all the papers that come before them. Besides it is becoming the custom to specialize, and business men call in specialists like Mr. Taylor, Mr. Day and Mr. Gantt to do such work for them, and those who do call in such experts are the men who in the future will achieve the greatest success.

Mr. Gantt.—The problem Mr. Day has run up against, that exceedingly efficient equipment is of little value unless you have efficient management, is true; and I might add that an exceedingly efficient equipment placed in an unsatisfactory building is also a very serious mistake. The absolute necessity of having your building suit the equipment and the management is equally important with having proper equipment of electrical drives and high power machinery.

Mr. John Calder.—Referring to Mr. Day's graphical method of illustrating certain routine in respect to manufacturing in the shop, I will say I think that is one of the most useful methods which a manager can have before him. It can be carried out in many different ways, so that not only the manager can from time to

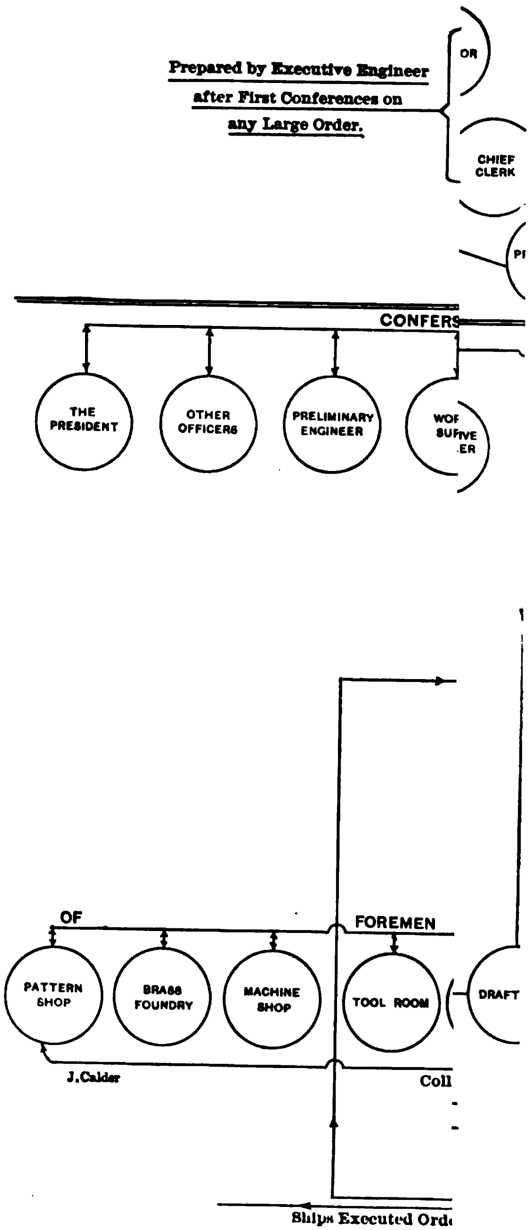
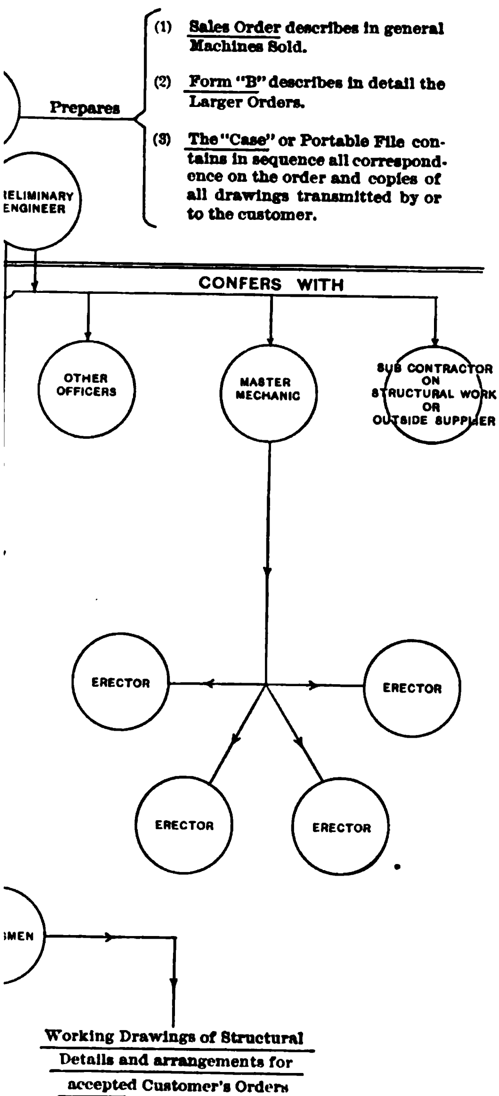

Prepared by Executive Engineer
after First Conferences on
any Large Order.
OR
CHIEF
CLERK
CONFERS
THE
PRESIDENT
OTHER
OFFICERS
PRELIMINARY
ENGINEER
OF
FOREMEN
PATTERN
SHOP
BRASS
FOUNDRY
MACHINE
SHOP
TOOL ROOM
DRAFT
J. Calder
Coll
Ships Executed Ord

Fig. :


Prepares
(1) Sales Order describes in general Machines Sold.
(2) Form "B" describes in detail the Larger Orders.
(3) The "Case" or Portable File contains in sequence all correspondence on the order and copies of all drawings transmitted by or to the customer.
RELIMINARY ENGINEER
CONFERS WITH
OTHER OFFICERS
MASTER MECHANIC
SUB CONTRACTOR ON STRUCTURAL WORK OR OUTSIDE SUPPLIER
ERECTOR
ERECTOR
ERECTOR
ERECTOR
MEN
Working Drawings of Structural Details and arrangements for accepted Customer's Orders

time refresh his memory as to the duties of the men by graphically illustrating to them, but he can also have the reference there before his eyes in the event of new men coming in, and by means of that graphic representation, can show them how to pick up their work much more quickly and put it through. It also enables one to pick out bad methods and prevent work retrograding. I would say, in conclusion, that the method Mr. Day has brought forward can be used generally, broadly, and also in detail, with great success. I hand in samples of charts which I have drawn up and use daily in the practical work of production. (Fig. 288.)

*Mr. Charles Day.**—I have endeavored to point out in my paper the importance of giving equal consideration to the numerous factors which together make up a complete manufacturing plant.

Reference was made to the need of designing buildings adapted to the requirements of manufacture, and I wish to dwell on this point further. Buildings are repeatedly erected which act as a continual handicap on economic production, and unless they are designed by one thoroughly familiar with the contemplated work, equipment, routing, future developments, etc., this result is sure to follow.

The advantages of electrical transmission and the system of motor driving best suited to a given plant are so interdependent with the type of management and the character of output that general statements as to resulting economies are most misleading.

The principle of fundamental analysis is as applicable to the study of shop equipment as shop management, and a thorough study of details, with a view to their relation to the problem as a whole, is absolutely necessary if efficient results are desired.

The value of the graphical method of presenting complex problems has been fully brought out in the discussion, the interesting charts shown by Mr. Calder illustrating further the advantages of this scheme.

---

* Author's Closure, under the Rules.

No. 1002.*

A GRAPHICAL DAILY BALANCE IN MANUFACTURE.

BY H. L. GANTT, SCHENECTADY, N. Y.
(Member of the Society.)

1. At the December meeting in 1901 the writer presented a paper entitled "A Bonus System of Rewarding Labor," in which was given an account of the results gotten under that system at the works of the Bethlehem Steel Company, and a description of the method employed.

The paper dealt particularly with the method of setting a task and with the reward for its accomplishment. It consisted briefly in setting as a task for a day's work the amount that a good man could reasonably be expected to accomplish, and paying the man a substantial amount in addition to his day's wages if the whole amount was done. If less than that amount was done he simply got his day's wages.

The result of this system, when the task was set in an intelligent manner and accompanied by a suitable compensation, was an efficiency of operation so far beyond that obtained by the ordinary day or piece-work method that it attracted a great deal of attention.

This centering of the attention on the result had, however, a serious disadvantage, for it withdrew the attention from the most important parts of the paper—namely, that describing the method of setting the task, and that referring to the method of operating the system by which an exact record was kept.

The method of setting the task is substantially that developed by Mr. Fred W. Taylor for setting piece-rates, and was described at some length. His paper before the present meeting further elucidates that part.

The routine operation of the system, which involves keeping

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

FOUNDRY PROD

A. L. CO. SCHEN

PART.		Bell Stand.		Exhaust Pipe.		Tender Frame Center Pin.		Eng Tru Swi Bols
PATTERN NO.		17,212		17,989		16,927		16,…
PATTERN DUE.		2—2		2—2		2—2		2-…
PATTERN REC'D.		1—22		1—22		2—6		2…
NO. WANTED PER DAY.		1		1		1		1
TOTAL NO. WANTED.		8		8		8		8
NUMBER MOULDED.		Daily	Total	Daily	Total	Daily	Total	Daily
1908 Feb.	2							
	3			1	1			
	4			2	3			
	5			2	5			1
	6							
	7	7		1 1	5			
	9			2	7	2	2	1
	10							1
	11	4	4					1
	12	1 2	5	1	8	2	4	1
	13					3	7	1
	14	1	6					1
	16	2	8			1	8	1
	17							
	18							
	19							
	20							
	21							
	23							
	24							
	25							
	26							

Begin moulding not later than date opposite *upper heavy* line.
Finish " " " " " *lower* " "

THIS IS A PORTION OF AN ORDER SHOWING HOW THE RECORDS WERE
THEY ARE USUALLY H

FI

'.

H. L. GANTT.

TION SHEET.

ADY WORKS.

ORDER NO. 88
8 ENGINES D. L. & W.

Grate Bar.		Grate Side.		Grate Side.		Ash Pan End.		Ash Pan Side.		Grate Frame Support.		Grate Bar.	
19,458		18,953		18,954		21,843		21,841		18,959		18,961	
2—2		2—2		2—2		2—2		2—2		2—2		2—2	
2—9		2—10		2—10		2—10		2—10		2—14		2—14	
8		2		2		1		1		1		1	
64		16		16		8		8		8		8	
Daily	Total	Daily	Total	Daily	Total	Daily	Total	Daily	Total	Daily	Total	Daily	Total
	P												
3	3	1 P	1	1 P	1	P		P			.		
1 8	10	2	3	2	3	1	1						
7 2	5	1	4	1	4	2	3						
		2	6	2	6	*1*	2	3	3				
8	13	1	7	1	7					P		P	
1 5	17	1	8	1	8	2	4	1	4	3	3	2	2
1 8	24	1	9	1	9	2	6			4	7	2	4
2 8	30	1	10	1	10	2	8	2	6	1	8	*1* 2	5
1 8	37	2	12	2	12			2	8			*1* 1	5
8	45	2	14	2	14								
8	53	2	16	2	16								
1 7	59											1	6
5	64											1	7
												1	8

.LY KEPT. THE FIGURES IN ITALICS REPRESENT CONDEMNATIONS.
) IN RED INK.

an exact daily record of the work done, was not, however, so clearly explained, and it is to that subject that this paper is devoted.

2. *Man's Record.*—In order to operate such a system we must not only have an exact record of what each workman does every day in order to find out whether he has earned his bonus or not, but must have beforehand an exact knowledge of the work to be done and how it is to be done. This amounts to keeping two sets of balances: one, of what each workman should do and did do; the other, of the amount of work to be done and is done. The former, or man's record, is concerned with the payment of the bonus, and consists in an exact comparison of what should be done as determined by our investigations, and what has been done as shown by the daily reports.

3. *Daily Balance of Work.*—The latter is a balance of work on each order, and should show at a glance each day just what has been done and what remains to be done, in order to enable us to lay out the work for the next day in the most economical manner. The importance of such a balance has been long recognized, but the difficulty of getting it is such that it has seldom been attempted. Many concerns get a weekly or monthly balance; but in both of these cases the information is usually obtained too late to prevent delays in work. Again the value of a balance is dependent largely upon its availability; in other words, upon the ease with which the desired information can be obtained from it. With this idea in mind the writer devised a combined schedule for work and a balance sheet that is largely graphical in its nature. On it dates are represented by positions, and when work is not done on consecutive days, there are no entries in consecutive positions. This practice enables the foreman or superintendent to see at a glance what work is going along properly. Such schedules can be made out for all classes of work, and a description of one or two will amply illustrate the principle.

4. *A Foundry Balance.*—Fig. 289 represents such a balance sheet and schedule for a foundry. At the heads of the various vertical columns are the names of the pieces to be cast, under each is its pattern number; then, in order, when the pattern is due at the foundry, when it is received, the number wanted per day, and the total number wanted. Below, each column is divided into two columns headed *daily* and *total.* These are crossed by hori-

zontal lines representing consecutive working days, on each of which is entered in the proper column the number of pieces made that day and the total number made to that date. Each column is crossed by two heavy horizontal lines, the upper one opposite the date at which the work should be begun, and the lower one opposite the date at which the work should be completed. These lines are usually red, and have been very appropriately named *danger lines*. The position of the entries with reference to these danger lines and the amounts of those entries show to what extent the schedule is being lived up to. If the schedule is being well followed the entries are always in the neighborhood of the red lines, or above them.

Fig. 289 represents a portion of an actual order showing how it was filled in the foundry of the Schenectady works. If there is no graphical check on the operations of the foundry, the work that is wanted during a certain week may be spread over three or four.

It is an extremely difficult matter for a foreman to get the work done exactly in the order it is wanted. For instance, if we are building two locomotives per day, each requiring four driving boxes, it seems an extremely difficult thing for him to get every day, without fail, at least eight driving boxes. There is a constant tendency when he is rushed with work to drop to seven or six with a corresponding decrease in output of locomotives. This tendency to give about what is wanted rather than exactly what is wanted, is the most common obstacle to getting the full output of a plant.

5. *A Daily Balance as a Permanent Record.*—This balance sheet shows not only how much work was done each day, but is a permanent record of exactly how the order was filled, which can be compared with the record of the previous and subsequent orders. This is best illustrated by a study of Fig. 289, which shows exactly where failure to comply with the schedule occurred. The letter *P* entered in some of the columns shows graphically the reason for the castings being behind. The pattern was not received until the date indicated. Similar sheets might show that it was the draftsman and not the pattern-maker who was to blame.

6. *A Machine Shop Balance and Routing Sheet.*—Fig. 290 is a similar balance sheet for work done in a machine shop on a series of locomotive frames and rails. The order in which the various operations are to be performed has been determined, and the

A. L. CO. PROD

SCHENECTADY WORKS

PART		FRAMES							
PUR ORD; SKETCH; PAT. OR CARD DR. No.									
OPERATION		REC'D		PLANED		SLOTTED		DRILLE	
TO BE BEGUN									
TO BE FINISHED									
NUMBER WANTED		15		15		15		15	
NUMBER FINISHED		DAILY	TOTAL	DAILY	TOTAL	DAILY	TOTAL	DAILY	TO
1903 JAN	20	2	2	2	2				
	21	2	4						
	22			2	4				
	23	1	5						
	24	2	7	1	5	3	3		
	25	4	11	2	7	1	4		
	27								
	28	1	12	2	9	3	7	2	[illegible]
	29	2	14	1	10	1	8	1	[illegible]
	30	1	15	1	11	2	10	1	[illegible]
	31			3	14	1	11	1	[illegible]
FEB	2					1	12	1	[illegible]
	3			1	15	1	13	3	[illegible]
	4							2	[illegible]
	5							2	[illegible]
	6					2	15		
	7							2	[illegible]
	9								
	10								
	11								
	12								
	13								
	14								
	16								
	17								
	18								
	19								
	20								
	21								
	23								
	24								
	25								
	26								

RECOR

FIG. 2

H. L. GANTT.

[ON SHEET

HINE SHOP No. 1.

ORDER No. 77
15 ENGINES N. Y. C.

		RAILS.											
SSEM'D		REC'D		PLANED		SLOTTED		RE-PL-TOP		RE-PL-BOT		DRILLED	
15		30		30		30		15		15		30	
Y	TOTAL	DAILY	TOTAL	DAILY	TOTAL	DAILY	TOTAL	DAILY	TOTAL	DAILY	TOTAL	DAILY	TOTAL
		6	6										
		6	12	6	6								
				4	10								
				2	12	4	4						
		6	18	4	16			1	1	1	1'		
						4	8	3	4	3	4		
		4	22	4	20	2	10						
		4	26	4	24	4	14	2	6	2	6	4	4
								1	7	1	7	4	8
		4	30	2	26	4	18	2	9	2	9		
	2			2	28	4	22	1	10	1	10		
	3			2	30	6	28	3	13	3	13	2	10
	5					2	30	2	15	2	15	4	14
	6											4	18
	8											6	24
	9											4	28
	11												
	12											2	30
	13												
	14												
	15												

CTUALLY KEPT.

A. L. CO. PROD

SCHENECTADY WORKS,

PART		FRAMES.							
PUR ORD; SKETCH; PAT. OR CARD DR. NO.									
OPERATION		REC'D		PLANED		SLOTTED		DRILL	
TO BE BEGUN									
TO BE FINISHED									
NUMBER WANTED		15		15		15		15	
NUMBER FINISHED		DAILY	TOTAL	DAILY	TOTAL	DAILY	TOTAL	DAILY	TO
1903 JAN	20	2	2	2	2				
	21	2	4						
	22			2	4				
	23	1	5						
	24	2	7	1	5	3	3		
	26	4	11	2	7	1	4		
	27	1	12						
	28	2	14	2	9	3	7		
	29	1	15	1	10	1	8		
	30			1	11	2	10		
	31			3	14	1	11		
FEB	2					1	12		
	3			1	15	1	13		
	4								
	5					2	15		
	6								
	7								
	9								
	10								
	11							2	
	12							1	
	13							1	
	14							1	
	16							1	
	17							2	
	18							1	
	19							1	
	20							2	
	21							1	
	23							2	
	24								
	25								
	26								

FIG

H. L. GANTT.

ION SHEET.

ORDER No. 77

'HINE SHOP NO. 1.

15 ENGINES N. Y. C.

…SSEM'D		RAILS.											
		REC'D		PLANED		SLOTTED		RE-PL-TOP		RE-PL-BOT		DRILLED	
15		30		30		30		15		15		30	
…LY	TOTAL	DAILY	TOTAL	DAILY	TOTAL	DAILY	TOTAL	DAILY	TOTAL	DAILY	TOTAL	DAILY	TOTAL
		6	6										
		6	12	6	6								
				4	10								
				2	12	4	4						
		6	18	4	16			1	1	1	1		
						4	8	3	4	3	4		
		4	22	4	20	2	10						
		4	26	4	24	4	14	2	6	2	6	4	4
								1	7	1	7	4	8
		4	30	2	26	4	18	2	9	2	9		
				2	28	4	22	1	10	1	10		
				2	30	6	28	3	13	3	13	2	10
						2	30	2	15	2	15	4	14
												4	18
												6	24
												4	28
												2	30
	1												
	2												
	3												
	4												
	5												
	7												
	8												
	9												
	10												
	12												
	13												
	15												

THIS TABLE SHOWS THE WAY FIG. 2 WOULD LOOK IF THE WORKS WERE SHORT OF FRAME DRILLING CAPACITY.

consecutive columns devoted to the operations in their proper order. You will note that on this sheet, which is an actual record of work, the consecutive operations were performed promptly, and that there was no serious delay.

Fig. 291 represents a record of the same work as it would appear if the works were short of frame-drilling capacity, and the drilling of frames were not done promptly. If it is impossible to make up the delay thus caused the output is limited by it. Such sheets show at a glance where the delays occur, and indicate what must have our attention in order to keep up the proper output. If the delay is always on the same operation we know that we must either get more output from the machines doing that work, or get more machines. Lines representing when work should be begun and when it should be finished are used on the machine shop sheets as well as on the foundry sheet, but have been left off to avoid confusion.

7. *A Graphical Balance as a History.*—A complete set of such sheets for all the work being done in a plant gives a complete schedule and a daily record of what is being done, and is of the greatest possible advantage if an attempt is to be made to improve the conditions or increase the output of the plant. In fact, if the improvement in the operation of a plant is to be made in a scientific manner, exact knowledge of what is taking place each day is absolutely necessary. Without it money is often spent wastefully, and but a small proportion of the desired results obtained. In large plants run without such a system of balances it is frequently impossible to tell just what is holding back the output, and then the value of such a balance is out of all proportion to the cost of obtaining it. By using the graphical form its value is very much increased, for the general appearance of the sheet is sufficient to tell how closely the schedule is being lived up to; in other words, whether the plant is being run efficiently or not. Moreover, such a balance is a history of the way the work went through the shop and is readily comparable with similar work done previously or subsequently, thus enabling us to form a definite idea as to whether the plant is being run more or less efficiently. The balance of work sheet then gives us a daily analysis of how the work is progressing, and in its graphical form is so easily read that both foreman and superintendents find it of great value. The man's record shows the efficiency of each man, and the two taken together give us

the knowledge, in the clearest way, of what should be done to increase our output.

8. *Value of Balance not Dependent upon Method of Compensation.*—It is not the intention of this paper to discuss the making of schedules for doing work, or instruction cards for the workmen to follow, or indeed the subject of compensation for work done, for the keeping of a daily balance of work done and a record of the men doing it are invaluable, no matter what the method of compensation. In fact, the writer has found the *man's record* when work was done by the day to be of the highest value, for when the men realize that not only their chance for increase of wages, but that of holding their positions depends upon the amount and quality of their work, they become very much more efficient. Add to this the fact that efficient men paid in proportion to their efficiency are invariably better satisfied than less efficient, cheaper men, and we have an added reason for keeping the man's record. Again a workman easily forgets how many days he has been absent, and how much poor work he has done, and an occasional glance at his record often does him a great deal of good. The writer first kept such a record in the foundry of the Midvale Steel Company thirteen years ago, and found it so valuable that he has always done it since when possible. Such record sheets are so easily gotten up and of so many kinds that the writer has not considered it necessary to illustrate them.

9. *The Graphical Balance and the Foreman.*—Next to the superintendent the most overworked people in the ordinary manufacturing plant are the foremen. Their duties may be summed up as follows, in the order of their importance: to get their work out on time; to get it out economically; to improve their methods. Add to their primary duties a multitude of others depending upon them, and but little time is left for thought, or investigation, on which depends improvement. When they are rushed, therefore, improvement is naturally the first thing to suffer. Further pushing causes economy to be sacrificed, for the work must get out, and the foreman has not time to go over and over his orders to see just what is the most economical arrangement of his work. Here is where the graphical schedule comes to his assistance, for he can see at a glance just what is behind or what should be done next. There has been but little difficulty in getting foremen to recognize the value of such a bal-

ance, and I have yet to learn of one, who, having gotten such a sheet in full operation, was willing to give it up.

10. *Cost of Keeping Balances.*—The question is frequently asked as to the cost of keeping these records and balances. In reply I have to say that if such cost were ten times what it is, it would cut no figure.

In day work we buy a man's time, and he frequently gives but little else. Our store-keeper checks exactly the materials we buy, but nobody knows exactly what the day workman has done in his ten hours; although we know labor to be the most difficult commodity we have to buy, we give it the least systematic study, and my effort to get an exact record of what we get for our money is the first step toward purchasing it in an intelligent manner. With regard to the balance of work, I can only say that it is hard to estimate the cost of lack of harmony in a plant, and the increase in efficiency produced by getting materials in their proper order rather than according to the judgment of the various foremen is greater than is usually realized.

The fact that, as far as the writer's experience goes, the foremen are not only willing to use these graphical sheets, but are glad to do so in order to make their work harmonize with that of other departments, is the strongest proof of the value of the graphical over the other forms of balance.

The value of a balance of some sort is too well understood to need discussion, and the only reason that it has not been adopted is often the fancied cost of getting it. As a matter of fact, all I have suggested can usually be gotten by the ordinary time and cost keeping force with but little help, and frequently without any. It is so closely allied to the time and cost keeping that when all are done together by the best modern method, the reduction of labor in getting the time and cost often more than offsets the increase due to keeping the mens' records and the balance of work. The method referred to is the *time and production card* system, of which the following is a description. There are conditions under which the system to be described here may be modified; in fact, it is not always found possible to introduce it exactly as described, which, however, is the ideal method of operating it and should be approximated as nearly as possible. It was first introduced substantially in this form by Mr. Fred. W. Taylor at the works of the Bethlehem Steel Company.

11. *Time and Production Card System.*—In its best development, a card is assigned the day previous to every man who is expected in at 7 A.M. the next day. Each of these cards is stamped with a rubber stamp 7 A.M. and the date. These cards are placed in a rack, which has a properly numbered space for each man, who takes it from his own card and no other.

Any men coming in after 7 A.M. are not allowed access to the rack, but must get their cards from the office, where the cards are marked properly by a time stamp with the exact time each man comes in.

Without any delay each man goes directly to the work that has been assigned to him, and while his machine is running, fills in on the card his name, his number, the order number, the machine number and the kind of work he is doing. At the end of the day he enters on his card the number of pieces that have been correctly finished, and the card is signed by the foreman or inspector, certifying that all of the entries are correct. If there have been errors in the work the foreman or inspector does not sign the time card, but makes out a supplementary card stating the exact nature of the errors, etc., and pins this card to the time card.

Fig. 292 represents a suitable form of *day work* card for use in some of the machine shops of the American Locomotive Company in connection with this system.

At the end of the day, or at noon the men are allowed access to the card racks as soon as the whistle has blown, and each man deposits his card in the proper pocket, an observer noting that a man deposits one card only.

Men coming in after noon get their cards in the same manner as in the morning; the cards being previously stamped with the hour work begins, and placed in the rack. Men who do not go out at noon do not need to change their cards.

When the men have gone out at the end of the day or at noon, the cards in the rack are stamped by means of a rubber stamp with the time the work ends.

The preferable form of card is a square one on paper stout enough to be shuffled. In the upper right-hand corner of the card should be placed the man's number, the order number and the machine number.

As there is room for one order number and one machine number only on one card, the workman must give in his card at the office and get a new one whenever he goes either on a new order or another machine.

12. *Time and Man's Record.*—In order to get a record of the man's time and work for the day, all the cards bearing his number must be gotten together. If these do not give a total of the full number of working hours, the first card of the day must

ISSUED RETURNED.		MAN'S NO.
		ORDER NO.
MACHINE SHOP.	HOURS WORKED	MACHINE NO.

WORKMAN'S NAME

NO. PIECES FINISHED.	SYMBOL.		OPERATION NO.
HOURS.	RATE.	WAGES.	CONTRACTOR'S NO.

I HAVE INSPECTED THE ABOVE WORK AND ENTRIES AND BELIEVE THEM TO BE CORRECT.

ENTERED IN		
PAY SHEET	COST SHEET	RECORD SHEET

SIGNED BY THE FOREMAN OR HIS REPRESENTATIVE

A. L. CO. ENTER ONE ITEM ONLY ON A CARD.

FIG. 292.

show that he was late, or there must be a pass stating what time he went out. These passes should be of the same size as the cards, and be put in with the time cards and sorted out by the man's number, so that when the clerk begins to enter the time and record he will have all the information at hand. The men's record may serve as a pay sheet, thus involving only one set of entries. When the time is entered up, the clerk doing it enters his initial in the lower left-hand corner in the space marked "pay sheet."

13. *Cost.*—To get the cost on an order the cards are then sorted

by "order number," and when the clerk begins to enter up the time or wages against any order, he should have before him all the cards representing work on that order. He is thus enabled to make the final entry directly from the cards, thus doing the work with a minimum of clerical labor. The clerk enters his initial in the space designated for such entry on "cost sheet."

14. *Progress or Production.*—To get a record of the work on any order, the cards which have been sorted by order number are further sorted by name of part and operation. We thus get together the cards showing on an order the number of pieces on which a certain operation has been finished that day. These are added up and entered directly on the *Production or Progress* sheet. By this method we can keep an intelligible record of all the work done with a minimum of clerical labor.

15. *Difficulty of Getting a Daily Balance.*—It is not necessary for the purpose I have in mind to dwell further on the details, my object being only to show that the difficulty of getting this daily record of our men and a balance of work done is not so great as to be prohibitory. In other words, *it is an entirely feasible thing to know exactly all that has been done in a large plant one day before noon of the next, and to get a complete balance of work in order to lay out* THAT AFTERNOON *in a logical manner the work for the next day.*

16. *Value of such a Balance.*—The value of such a balance consists in the fact that it makes clear details that no observer, however keen he may be, can see by inspection. It shows us what work is behind and how much, and enables us to trace to its source the cause of any delay. The superintendent sees at a glance what he never could find out by observation or by asking questions. It shows him how efficiently a plant is being run and where the defects in operation are. In connection with the man's record, it is the most complete analysis we can make of the working of a plant, and the one that will help us most quickly to bring into their proper channels things that have been going haphazard. Such an analysis is far more important than an improved tool steel or a new set of piece-rates. It should be established before the introduction of either of these in order that we may have some means of measuring the gain made by their introduction, and it should remain after they are introduced to show that a forward step once taken is never retraced.

17. *Accounting and Operating.*—In conclusion the writer wishes to say that it is his opinion that we can do nothing in a manufacturing plant that will go so far toward increasing the output or the economy of operation as obtaining this exact knowledge of what is being done. The cost of getting it is almost nothing, and the methods of operation need not be disturbed in the least until an accumulation of knowledge points out the best course to pursue.

By the adoption of the methods outlined the accounting department ceases to be simply a critic of the manufacturing, and becomes an active assistant to every foreman and to the superintendent. In other words, the accounts cease to be simply records of production, and become potent factors in helping the producing departments.

18. *The Bonus System a Form of Profit Sharing.*—Having established these combined order, schedule, and production sheets, the next step is to pay *a bonus* to the head of each shop based on the extent to which he adheres to the schedule as laid out. These sheets thus do for the foreman what the *Instruction Card* does for the individual, and the final result of the system is harmonious working and a high degree of efficiency, a portion of the profits of which goes directly to the individual in proportion as his efforts tend to maintain that efficiency. Carried out to its logical end, therefore, the *Bonus System* as described in my previous paper becomes practically one of *profit sharing*, in which each man gets his portion of the profits as soon as he earns it.

In this paper I have confined myself as nearly as possible to general principles, using specific cases simply as illustrations. These principles are capable of further development and may be worked out in detail to suit the needs of many forms of manufacture.

DISCUSSION.

Mr. John Calder.—The method brought out by Mr. Gantt in his paper, of bringing before the superintendents of various departments the work of each day, is a method which in our establishment we call the "Pie Plate System." It consists of having a series of racks divided off much as they are in one of the racks where pies are displayed in a bakery. When an order comes into that department it is put in one of these shelves. Then it goes from there to the credit clerk, and when he disposes of it he puts it in the next compartment. Then it goes to the clerk whose business it is to look over the papers to see whether they are in proper shape to be written out, and he transfers it to a third compartment. So it goes on through until the work is completed in that department.

The advantage of this is that the manager coming in the department in the morning can look at that pie rack and, if he sees an accumulation of papers in any one compartment he knows there is something wrong. At noon all of the papers have to be returned to their proper place. Around certain of the compartments there are red circles drawn: those are danger points, and indicate that papers must not be allowed to accumulate there under any circumstances.

That same system is carried out in all the different departments, so that the manager of the business in walking through the shops can look at the pie plate boxes and judge of the general condition of the work in that department at a glance.

Mr. H. B. Ayers.—I have had this system in operation more than nine months and it has worked exceedingly well. We have seen a great increase in our output from its use.

To show how this system has helped me in getting out work I will take the frame job as an example. The sheets showed plainly it was the planing of the shoes and wedges which were holding up the work, and nothing else in the manufacture of the frame was giving us any trouble. Consequently I bolstered up that operation and we have had no trouble since. The same thing is true in the foundry department, and whenever the sheets have shown trouble along any line we have taken steps to remedy it. It is a fact that the output of our foundry has been increased six hundred per cent. in a year, although the rest of our shops have not shown any such increase. You may think this shows the foundry was doing very poorly before, and it was, but I want to give a great deal of credit for this showing to Mr. Gantt's system.

Mr. F. A. Halsey.—This paper of Mr. Gantt's is a striking illustration of the manner in which the minds of men in different parts of the country turn simultaneously to the same thing. The general idea embodied in this paper has sprung up in a good many shops, where the plans which embody it are known by various names, such as "Follow-up System," "Work in Progress Record," etc. These plans have, in many cases, no similarity except in the results aimed at, which are the placing before the foremen of the dates when different pieces of work are expected from them, and, likewise, the reporting back to the office of the fact that the work has been completed on time, or not, as the case may be.

There can be no doubt of the great value of this general idea in works of such magnitude that the keeping of the work in progress is burdensome, or even impossible, by the simple exercise of memory.

Mr. McGeorge.—Mr. Gantt in his paper spoke of not requiring any further clerical help. I would like to inquire how he manages that? Does he appoint special corps of clerks for this purpose, or has each foreman a clerk? Then again, who settles when these various parts shall be assembled? In other words, who fills out the sheets to begin with? Then he also spoke of a danger signal—a red line. I would like to ask who puts that red line on?

Mr. Charles Day.—During a recent investigation of Mr. Gantt's work I was impressed most strongly by the splendid support he was receiving from those in the shop with whom he came directly in contact. It is usually taken for granted that opposition will be encountered in the shop, but in the Schenectady Locomotive Works the various superintendents and foremen, as well as the workmen, with whom I conversed, were most enthusiastic, desiring at once to indicate how their work had been simplified since the introduction of Mr. Gantt's methods.

We have all heard with interest Mr. Ayers' remarks, but I am sure that a score of the shop men who have been associated with the work during the past year would testify with equal force to the utility of the work. This, in my mind, is the strongest proof of the value of the graphical daily balance.

Mr. Peck.—I have run across a number of mechanical engineers who have visited our works from various parts of the country, and they seem to be more or less—and I am afraid some of them rather less than more—conversant with Mr. Gantt's system.

In the working out of the system throughout our shops we have found that it has a tendency to show up weak points, and that very often I have found the particular weak point was in myself. Several times I thought it would be a good idea to get hot-footed after somebody. Then I would trace back on Mr. Gantt's sheets and ascertain that I was the man that ought to be got after instead of some other fellow. At one time we were studying shop systems very carefully, and I was on a committee to devise some method of following work through the shop. Being a reader of the *American Machinist* and several other mechanical journals, I looked up various systems, and may say that I read and studied probably twenty-five different systems with the result that I honestly believe that Mr. Gantt's system is the simplest, the cheapest and the best I have ever run across.

*Mr. Gantt.**—In answer to Mr. McGeorge's question I may say that the whole schedule, red lines and all, should originate in a planning department such as is advocated by Mr. Taylor, but as few plants have such a department, it is usually impossible at first to do this work as it should be done, and the schedules have to be made out by those most available for the purpose.

Comparing the manufacture of locomotives with that of any other large machines, a very casual investigation will be sufficient to show that the art of building locomotives is by far the most fully developed, and that the harmony between the different portions of a locomotive plant is much more perfect than that in any other plant of the same size building large machinery. This is so because locomotives are always built according to a schedule, which is the evolution of more than half a century's work in the same line.

What time and evolution have done for the building of the locomotive, Mr. Taylor does for the building of machinery in general by means of his planning department. What I have done is to put in a graphical form not only the schedule for building the locomotive, but to show graphically how that schedule is carried out. At the locomotive works we made no attempt to modify or criticize the existing schedule, but simply recorded how the schedule was lived up to.

These combined schedules and records become a history of how the work went through the shop and will ultimately supply the information needed in modifying the schedules so as to get still greater harmony between the different departments and greater economy of manufacture.

Where pretty complete schedules exist, as in most locomotive plants, anybody in authority can see that they are made out in a graphical form and lived up to. Three examples given below will show how this work can be started under these conditions. Even where there are no well defined schedules there is always a certain

* Author's Closure, under the Rules.

amount of knowledge that takes their place, and the collection of this knowledge and the putting of it in a graphical form can always be done. Such schedules are necessarily imperfect at first, but are far better than nothing, and, if the records are properly kept, may be rapidly improved, especially if a planning or production department is organized to develop them as rapidly as possible.

The three examples referred to above are as follows:

At the Manchester Works of the American Locomotive Company, Mr. Ayres, the superintendent, gave his personal attention to having them started in the foundry. He has told you his results.

At the Schenectady Works Mr. Peck, foreman of number one machine shop, personally looked after their introduction in his shop. He has told you of his work.

At the Brooks Works Mr. Reid, the assistant superintendent started them in the foundry. He is not here, so I shall tell you of his results. He personally put the red lines on to start with, and had the sheets sent to his office every morning at ten o'clock with the previous day's work written up to see how the schedule was being lived up to. They were sent back with his written comments to the foreman in time for him to arrange his work for the next day. The result of this was a prompt improvement in the output of the foundry. The best illustration I can give you of his success is to show you these order sheets for thirty-five locomotives filled by that foundry about eight months after the system was started. (Here were shown several actual schedule sheets of this order with the red lines and entries exactly as kept in the foundry office as reproduced in Figs. 289, 290 and 291.

If you can see the red lines and the entries, you can see how the schedule was lived up to. Suffice it to say that out of a total of over nine thousand castings, none were more than five days behind schedule time, and only two, which were replacements, more than four days. This is a record that any foundry might be proud of. Don't imagine, however, that the system alone did it. The system simply supplied the means by which it could be done, and the man trained to use the system and to know its value got the results. The fact that a man capable of using the system must be found or developed is one reason why it takes so long to get it properly started.

There is one other thing which I did not quite get to in presenting my paper—the difficulty of getting this daily balance: "It is not necessary for the purpose I have in mind to dwell further on the details, my object being only to show that the difficulty of getting this daily record of our men and the balance of work done is not so great as to be prohibitory." *If it cost fifty times what it does, it would pay.* To know exactly all that was done in a large plant one day before noon of the next, and to get a complete balance of work in order to lay out that afternoon in a logical manner the work for the next day, enables us to *manage a large plant as intelligently as a small one.*

The value of such a balance consists in the fact that it makes clear details which no observer can see by inspection. It shows what work is behind, and how much, and enables us to trace to its source any cause of the delay. The superintendent sees at a glance what he never could find out by observation or by asking questions. In connection with a man's record it is the most complete analysis we can make of the working of a plant, and the one which will help us most to bring into their proper channels things that have been going haphazard.

In conclusion I have to say it is my opinion that we can do nothing in a manufacturing plant which will go so far towards increasing the output and the economy of operation as obtaining this exact knowledge of what is being done. By the adoption of the method which I have outlined the accounting department ceases to be simply a critic of the manufacturing and becomes an active assistant to every foreman and to the superintendent.

No. 1003.*

SHOP MANAGEMENT.†

BY FRED. W. TAYLOR, PHILADELPHIA.

(Member of the Society.)

The following is an index to the subjects treated in this paper:

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV., of the *Transactions*.

† For further discussion on this topic consult *Transactions* as follows:

No. 909, vol. xxii., p. 1040: "Drawing Room and Shop System." F. O. Ball.
No. 928, vol. xxiii., p. 341: "Bonus System for Rewarding Labor." H. L. Gantt.
No. 965, vol. xxiv., p. 250: "Gift Proposition for Paying Workmen." Frank Richards.
No. 341, vol. x., p. 600: "Gain Sharing." Henry R. Towne.
No. 449, vol. xii., p. 755: "Premium Plan of Paying for Labor." F. A. Halsey.
No. 647, vol. xvi., p. 856: "Piece Rate System." F. W. Taylor.

Accurate Scientific Time Study.

The Task Idea in Management.

Illustrations of the Practical Results Attained Through the Application of the Task Idea in Management.

Standards.

Planning Department.

1. Through his business in changing the methods of shop management, the writer has been brought into intimate contact for several years with the organization of manufacturing and industrial establishments, covering a large variety and range of product, and employing workmen in many of the leading trades.

2. In taking a broad view of the field of management, the two facts which appear most noteworthy are:

(1) What may be called the *great unevenness*, or lack of uniformity shown, even in our best run works, in the development of the several elements, which together constitute what is called *the management.*

(2) *The lack of apparent relation* between good shop management and the payment of dividends.

3. Although the day of trusts is here, still practically each of the component companies of the trusts was developed and built up largely through the energies and especial ability of some one or two men who were the master spirits in directing its growth. As a rule, this leader rose from a more or less humble position in one of the departments, say in the commercial or the manufacturing department, until he became the head of his particular section. Having shown especial ability in his line, he was for that reason made manager of the whole establishment.

4. In examining the organization of works of this class, it will frequently be found that the management of the particular department in which this master spirit has grown up, towers to a high point of excellence, his success having been due to a thorough knowledge of all of the smallest requirements of his section, obtained through personal contact, and the gradual training of the men under him to their maximum efficiency.

5. The remaining departments, in which this man has had but little personal experience, will often present equally glaring examples of inefficiency. And this, mainly because management is not yet looked upon as an art, with laws as exact, and as clearly defined, for instance, as the fundamental principles of engineering, which demand long and careful thought and study, but rather as a question of men, the old view being that if you have the right man the methods can be safely left to him.

6. The following, while rather an extreme case, may still be looked upon as a fairly typical illustration of the *unevenness of management.* It became desirable to combine two rival manufactories of chemicals. The great obstacle to this combination, however, and one which for several years had proved insurmountable, was that the two men, each of whom occupied the position of owner and manager of his company, thoroughly despised one another. One of these men had risen to the top of his works through the office at the commercial end, and the other had come up from a workman in the factory. Each one was sure that the other was a fool, if not worse. When they were finally combined it was found that each was right in his judgment of the other in a certain way. A comparison of their books showed that the *manufacturer* was producing his chemicals more than forty per cent cheaper than his rival, while the business man made up the difference by insisting on maintaining the highest quality, and by his superiority in selling, buying, and the management of the commercial side of the business. A combination of the two, however, finally resulted in mutual respect, and saving the forty per cent. formerly lost by each man.

7. The second fact that has struck the writer as most noteworthy is that there is no apparent relation in many, if not most cases, between good shop management and the success or failure of the company, many unsuccessful companies having good shop management while the reverse is true of many which pay large dividends.

8. We, however, who are primarily interested in the shop, are apt to forget that success, instead of hinging upon shop management depends in many cases mainly upon other elements, namely, —the location of the company, its financial strength and ability, the efficiency of its business and sales departments, its engineering ability, the superiority of its plant and equipment, or the protection afforded either by patents, combination, location or other partial monopoly.

9. And even in those cases in which the efficiency of shop management might play an important part it must be remembered that for success no company need be better organized than its competitors.

10. The most severe trial to which any system can be subjected is that of a business which is in keen competition over a large territory, and in which the labor cost of production forms a large element of the expense, and it is in such establishments that one would naturally expect to find the best type of management.

11. Yet it is an interesting fact that in several of the largest and most important classes of industries in this country shop practice is still twenty to thirty years behind what might be called modern management. Not only is no attempt made by them to do tonnage or piece work, but the oldest of old-fashioned day work is still in vogue in which one overworked foreman manages the men, and the workmen are still herded in classes, all of those in a class being paid the same wages, regardless of efficiency.

12. In these industries, however, although they are keenly competitive, the poor type of shop management does not interfere with dividends, since they are in this respect all equally bad.

13. It would appear, therefore, that as an index to the quality of shop management the earning of dividends is but a poor guide.

14. Any one who has the opportunity and takes the time to study the subject will see that neither good nor bad management is confined to any one system or type. He will find a few instances of good management containing all of the elements necessary for permanent prosperity for both employers and men under ordinary day work, the task system, piece work, contract work, the premium plan, the bonus system and the differential rate; and he will find a very much larger number of instances of bad management under these systems containing the elements which lead to discord and ultimate loss and trouble for both sides.

15. If neither the prosperity of the company nor any particular

type or system furnishes an index to proper management, what then is the touchstone which indicates good or bad management?

16. The art of management has been defined, "As knowing exactly what you want men to do, and then seeing that they do it in the best and cheapest way." No concise definition can fully describe an art, but the relations between employers and men form without question the most important part of this art. In considering the subject, therefore, until this part of the problem has been fully discussed, the remainder of the art may be left in the background.

17. The progress of many types of management is punctuated by a series of disputes, disagreements and compromises between employers and men, and each side spends more than a considerable portion of its time thinking and talking over the injustice which it receives at the hands of the other. All such types are out of the question, and need not be considered.

18. It is safe to say that no system or scheme of management should be considered which does not in the long run give satisfaction to both employer and employee, which does not make it apparent that their best interests are mutual, and which does not bring about such thorough and hearty co-operation that they can pull together instead of apart. It cannot be said that this condition has as yet been at all generally recognized as the necessary foundation for good management. On the contrary, it is still quite generally regarded as a fact by both sides that in many of the most vital matters the best interests of employers are necessarily opposed to those of the men. In fact, the two elements which we will all agree are most wanted on the one hand by the men and on the other hand by the employers are generally looked upon as antagonistic.

19. What the workmen want from their employers beyond anything else is high wages, and what employers want from their workmen most of all is a low labor cost of manufacture.

20. These two conditions are not diametrically opposed to one another as would appear at first glance; on the contrary, they can be made to go together in all classes of work, without exception, and in the writer's judgment the existence or absence of these two elements forms the best index to either good or bad management.

21. THIS PAPER IS WRITTEN MAINLY WITH THE OBJECT OF ADVOCATING HIGH WAGES AND LOW LABOR COST AS THE FOUNDATION OF

THE BEST MANAGEMENT, OF POINTING OUT THE GENERAL PRINCIPLES WHICH RENDER IT POSSIBLE TO MAINTAIN THESE CONDITIONS EVEN UNDER THE MOST TRYING CIRCUMSTANCES, AND OF INDICATING THE VARIOUS STEPS WHICH THE WRITER THINKS SHOULD BE TAKEN IN CHANGING FROM A POOR SYSTEM TO THE BETTER TYPES OF MANAGEMENT.

22. The condition of high wages and low labor cost is far from being accepted either by the average manager or the average workman as a practical working basis. It is safe to say that the majority of employers have a feeling of satisfaction when their workmen are receiving lower wages than those of their competitors; and on the other hand that very many workmen would feel contented if they found themselves doing the same amount of work per day as other similar workmen do and get more pay for it. Yet employers and workmen should alike look upon both of these conditions with apprehension, as they are either of them sure, in the long run, to lead to trouble and loss for both parties.

23. Through unusual personal influence and energy, or more frequently through especial conditions which are but temporary, such as dull times when there is a surplus of labor, a superintendent may succeed in getting men to work extra hard for ordinary wages. After the men, however, realize that this is the case and an opportunity comes for them to change these conditions, in their reaction against what they believe unjust treatment they are almost sure to lean so far in the other direction as to do an equally great injustice to their employer.

24. On the other hand, the men who use the opportunity offered by a scarcity of labor to exact wages higher than the average of their class, without doing more than the average work in return, are merely laying up trouble for themselves in the long run. They grow accustomed to a high rate of living and expenditure, and when the inevitable turn comes and they are either thrown out of employment or forced to accept low wages, they are the losers by the whole transaction.

25. The only condition which contains the elements of stability and permanent satisfaction is that in which both employer and employees are doing as well or better than their competitors are likely to do, and this in nine cases out of ten means high wages and low labor cost, and both parties should be equally anxious for these conditions to prevail. With them the employer can

hold his own with his competitors at all times and secure sufficient work to keep his men busy even in dull times. Without them both parties may do well enough in busy times, but both parties are likely to suffer when work becomes scarce.

26. The possibility of coupling high wages with a low labor cost rests mainly upon the enormous difference between the amount of work which a first-class man can do under favorable circumstances and the work which is actually done by the average man.

27. That there is a difference between the average and the first-class man is known to all employers, but that the first-class man can do in most cases from two to four times as much as is done on an average is known to but few, and is fully realized only by those who have made a thorough and scientific study of the possibilities of men.

28. The writer has found this enormous difference between the first-class and average man to exist in all of the trades and branches of labor which he has investigated, and this covers a large field, as he, together with several of his friends, have been engaged with more than usual opportunities for twenty years past in carefully and systematically studying this subject.

29. This fact is as little realized by the workmen themselves as by their employers. The first-class men know that they can do more work than the average, but they have rarely made any careful study of the matter. And the writer has over and over again found them utterly incredulous when he informed them, after close observation and study, how much they were able to do. In fact, in most cases when first told that they are able to do two or three times as much as they have done they take it as a joke and will not believe that one is in earnest.

30. It must be distinctly understood that in referring to the possibilities of a first-class man the writer does not mean what he can do when on a spurt or when he is over-exerting himself, but what a good man can keep up for a long term of years without injury to his health, and become happier and thrive under.

31. The second and equally interesting fact upon which the possibility of coupling high wages with low labor cost rests, is that first-class men are not only willing but glad to work at their maximum speed, providing they are paid from 30 to 100 per cent. more than the average of their trade.

32. The exact percentage by which the wages must be increased in order to make them work to their maximum is not a subject to

be theorized over, settled by boards of directors sitting in solemn conclave, nor voted upon by trades unions. It is a fact inherent in human nature and has only been determined through the slow and difficult process of trial and error.

33. The writer has found, for example, after making many mistakes above and below the proper mark, that to get the maximum output for ordinary shop work requiring neither especial brains, very close application, skill, nor extra hard work, such, for instance, as the more ordinary kinds of routine machine shop work, it is necessary to pay about 30 per cent. more than the average. For ordinary day labor requiring little brains or special skill, but calling for strength, severe bodily exertion and fatigue, it is necessary to pay from 50 per cent. to 60 per cent. above the average. For work requiring especial skill or brains, coupled with close application but without severe bodily exertion, such as the more difficult and delicate machinist's work, from 70 per cent. to 80 per cent. beyond the average. And for work requiring skill, brains, close application, strength and severe bodily exertion, such, for instance, as that involved in running a well run steam hammer doing miscellaneous work, from 80 per cent. to 100 per cent. beyond the average.

34. There are plenty of good men ready to do their best for the above percentages of increase, but if the endeavor is made to get the right men to work at this maximum for less than the above increase, it will be found that most of them will prefer their old rate of speed with the lower pay. After trying the high speed piece work for a while they will one after another throw up their jobs and return to the old day work conditions. Men will not work at their best unless assured a good liberal increase, which must be permanent.

35. It is the writer's judgment, on the other hand, that for their own good it is as important that workmen should not be very much over-paid, as it is that they should not be under-paid. If over-paid, many will work irregularly and tend to become more or less shiftless, extravagant and dissipated. It does not do for most men to get rich too fast. The writer's observation, however, would lead him to the conclusion that most men tend to become more instead of less thrifty when they receive the proper increase for an extra hard day's work, as, for example, the percentages of increase referred to above. They live rather better, begin to save money, become more sober, and work more steadily. And

this certainly forms one of the strongest reasons for advocating this type of management.

36. In referring to high wages and low labor cost as fundamental in good management, the writer is most desirous not to be misunderstood.

37. By high wages he means wages which are high only with relation to the average of the class to which the man belongs and which are paid only to those who do much more or better work than the average of their class. He would not for an instant advocate the use of a high-priced tradesman to do the work which could be done by a trained laborer or a lower-priced man. No one would think of using a fine trotter to draw a grocery wagon nor a Percheron to do the work of a little mule. No more should a mechanic be allowed to do work for which a trained laborer can be used, and the writer goes so far as to say that almost any job that is repeated over and over again, however great skill and dexterity it may require, providing there is enough of it to occupy a man throughout a considerable part of the year, should be done by a trained laborer and not by a mechanic. A man with only the intelligence of an average laborer, can be taught to do the most difficult and delicate work if it is repeated enough times; and his lower mental calibre renders him more fit than the mechanic to stand the monotony of repetition. It would seem to be the duty of employers, therefore, both in their own interest and that of their employees to see that each workman is given as far as possible the highest class of work for which his brains and physique fit him. A man, however, whose mental calibre and education do not fit him to become a good mechanic (and that grade of man is the one referred to as belonging to the "laboring class"), when he is trained to do some few especial jobs, which were formerly done by mechanics, should not expect to be paid the wages of a mechanic. He should get more than the average laborer, but less than a mechanic; thus insuring high wages to the workman, and low labor cost to the employer, and in this way making it most apparent to both that their interests are mutual.

38. To summarize, then, what should be aimed at in all establishments is:

1. That each workman should be given as far as possible the highest grade of work for which his ability and physique fit him.

2. Each workman should be called upon to turn out the maxi-

mum work which a first-rate man of his class can do and thrive under.

3. Each workman, when he works at the best pace of a first-class man, should be paid from 30 per cent. to 100 per cent., according to the nature of the work which he does, beyond the average of his class.

39. And this means *high wages* and a *low labor cost*. These conditions not only serve the best interests of the employer, but they tend to raise each workman to the highest level which he is fitted to attain by making him use his best faculties, forcing him to become and remain ambitious and energetic, and giving him sufficient pay to live better than in the past.

40. Under them the writer has seen many first-class men developed who otherwise would have remained second or third class all of their lives.

41. Is not the presence or absence of these conditions the best indication that any system of management is either well or badly applied? And in considering the relative merits of different types of management, is not that system the best which will establish these conditions with the greatest certainty, precision and speed?

42. In comparing the management of manufacturing and engineering companies by this standard, it is surprising to see how far they fall short. Few of those which are best organized have attained even approximately the maximum output of first-class men.

43. Many of them are paying much higher prices per piece than are required to secure the maximum product; while owing to a bad system, lack of exact knowledge of the time required to do work, and mutual suspicion and misunderstanding between employers and men, the output per man is so small that the men receive little if any more than average wages, both sides being evidently the losers thereby.

44. The chief causes which produce this loss to both parties are: First, and by far the most important: The profound ignorance of employers and their foremen as to the time in which various kinds of work should be done (and this ignorance is shared largely by the workmen).

Second: Their indifference and ignorance as to the proper system to adopt and the method of applying it, and as to the individual character, worth, and welfare, of their men.

45. On the part of the men the greatest obstacle to the attain-

ment of this standard is the slow pace which they adopt, or the loafing, soldiering or marking time, as it is called.

46. This loafing or soldiering proceeds from two causes. First, from the natural instinct and tendency of men to take it easy, which may be called natural soldiering. Second, from more intricate second thought and reasoning caused by their relations with other men, which may be called systematic soldiering.

47. There is no question that the tendency of the average man (in all walks of life) is toward working at a slow, easy gait, and that it is only after a good deal of thought and observation on his part or as a result of example, conscience, or external pressure that he takes a more rapid pace.

48. There are, of course, men of unusual energy, vitality and ambition who naturally choose the fastest gait, set up their own standards, and who will work hard, even though it may be against their best interests. But these few uncommon men only serve by forming a contrast to emphasize the tendency of the average.

49. This common tendency to "take it easy" is greatly increased by bringing a number of men together on similar work and at a uniform standard rate of pay by the day.

50. Under this plan the better men gradually but surely slow down their gait to that of the poorest and least efficient. When a naturally energetic man works for a few days beside a lazy one, the logic of the situation is unanswerable. "Why should I work hard when that lazy fellow gets the same pay that I do and does only half as much work?"

51. A careful time study of men working under these conditions will disclose facts which are ludicrous as well as pitiable.

52. To illustrate: The writer has timed a naturally energetic workman who, while going and coming from work, would walk at a speed of from three to four miles per hour, and not infrequently trot home after a day's work. On arriving at his work he would immediately slow down to a speed of about one mile an hour. When, for example, wheeling a loaded wheelbarrow, he would go at a good fast pace even up hill in order to be as short a time as possible under load, and immediately on the return walk slow down to a mile an hour, improving every opportunity for delay short of actually sitting down. In order to be sure not to do more than his lazy neighbor, he would actually tire himself in his effort to go slow.

53. These men were working under a foreman of good reputa-

tion and highly thought of by his employer, who, when his attention was called to this state of things, answered: "Well, I can keep them from sitting down but the devil can't make them get a move on while they are at work."

54. The natural laziness of men is serious, but by far the greatest evil from which both workmen and employers are suffering is the *systematic soldiering* which is almost universal under all of the ordinary schemes of management and which results from a careful study on the part of the workmen of what will promote their best interests.

55. The writer was much interested recently in hearing one small but experienced golf caddy boy of twelve explaining to a green caddy who had shown special energy and interest, the necessity of going slow and lagging behind his man when he came up to the ball, showing him that since they were paid by the hour, the faster they went the less money they got, and finally telling him that if he went too fast the other boys would give him a licking.

56. This represents a type of systematic soldiering which is not, however, very serious, since it is done with the knowledge of the employer, who can quite easily break it up if he wishes.

57. The greater part of the *systematic soldiering*, however, is done by the men with the deliberate object of keeping their employers ignorant of how fast work can be done.

58. So universal is soldiering for this purpose, that hardly a competent workman can be found in a large establishment, whether he works by the day or on piece work, contract work or under any of the ordinary systems, who does not devote a considerable part of his time to studying just how slow he can work and still convince his employer that he is going at a good pace.

59. The causes for this are, briefly, that practically all employers determine upon a maximum sum which they feel it is right for each of their classes of employees to earn per day, whether their men work by the day or piece.

60. Each workman soon finds out about what this figure is for his particular case, and he also realizes that when his employer is convinced that a man is capable of doing more work than he has done, he will find sooner or later some way of compelling him to do it with little or no increase of pay.

61. Employers derive their knowledge of how much of a given class of work can be done in a day from either their own experience, which has frequently grown hazy with age, from casual and

unsystematic observation of their men, or at best from records which are kept, showing the quickest time in which each job has been done. In many cases the employer will feel almost certain that a given job can be done faster than it has been, but he rarely cares to take the drastic measures necessary to force men to do it in the quickest time, unless he has an actual record proving conclusively how fast the work can be done.

62. It evidently becomes for each man's interest, then, to see that no job is done faster than it has been in the past. The younger and less experienced men are taught this by their elders, and all possible persuasion and social pressure is brought to bear upon the greedy and selfish men to keep them from making new records which result in temporarily increasing their wages, while all those who come after them are made to work harder for the same old pay.

63. Under the best day work of the ordinary type, when accurate records are kept of the amount of work done by each man and of his efficiency, and when each man's wages are raised as he improves, and those who fail to rise to a certain standard are discharged and a fresh supply of carefully selected men are given work in their places, both the natural loafing and systematic soldiering can be largely broken up. This can only be done, however, when the men are thoroughly convinced that there is no intention of establishing piece work even in the remote future, and it is next to impossible to make men believe this when the work is of such a nature that they believe piece work to be practicable. In most cases their fear of making a record which will be used as a basis for piece work will cause them to soldier as much as they dare.

64. It is, however, under piece work that the art of systematic soldiering is thoroughly developed; after a workman has had the price per piece of the work he is doing lowered two or three times as a result of his having worked harder and increased his output, he is likely to entirely lose sight of his employer's side of the case and become imbued with a grim determination to have no more cuts if soldiering can prevent it. Unfortunately for the character of the workman, soldiering involves a deliberate attempt to mislead and deceive his employer, and thus upright and straightforward workmen are compelled to become more or less hypocritical. The employer is soon looked upon as an antagonist, if not an enemy, and the mutual confidence which should exist

between a leader and his men, the enthusiasm, the feeling that they are all working for the same end and will share in the results, is entirely lacking.

65. The feeling of antagonism under the ordinary piece work system becomes in many cases so marked on the part of the men, that any proposition made by their employers, however reasonable, is looked upon with suspicion, and soldiering becomes such a fixed habit that men will frequently take pains to restrict the product of machines which they are running when even a large increase in output would involve no more work on their part.

66. On work which is repeated over and over again and the volume of which is sufficient to permit it, the plan of making a contract with a competent workman to do a certain class of work and allowing him to employ his own men subject to strict limitations, is successful.

67. As a rule, the fewer the men employed by the contractor and the smaller the variety of the work, the greater will be the success under the contract system, the reason for this being that the contractor, under the spur of financial necessity, makes personally so close a study of the quickest time in which the work can be done, that soldiering on the part of his men becomes difficult and the best of them teach laborers or lower-priced helpers to do the work formerly done by mechanics.

68. The objections to the contract system are that the machine tools used by the contractor are apt to deteriorate rapidly, his chief interest being to get a large output, whether the tools are properly cared for or not, and that through the ignorance and inexperience of the contractor in handling men, his employees are frequently unjustly treated.

69. These disadvantages are, however, more than counterbalanced by the comparative absence of soldiering on the part of the men.

70. The greatest objection to this system is the soldiering which the contractor himself does in many cases, so as to secure a good price for his next contract.

71. It is not at all unusual for a contractor to restrict the output of his own men and to refuse to adopt improvements in machines, appliances, or methods while in the midst of a contract, knowing that his next contract price will be lowered in direct proportion to the profits which he has made and the improvements introduced.

72. Under the contract system, however, the relations between employers and men are much more agreeable and normal than under piece work, and it is to be regretted that owing to the nature of the work done in most shops this system is not more generally applicable.

The writer quotes as follows from his paper on "A Piece Rate System":

73. "Coöperation, or profit sharing, has entered the mind of every student of the subject as one of the possible and most attractive solutions of the problem; and there have been certain instances, both in England and France, of at least a partial success of coöperative experiments.

74. So far as I know, however, these trials have been made either in small towns, remote from the manufacturing centres, or in industries which in many respects are not subject to ordinary manufacturing conditions.

75. Coöperative experiments have failed, and, I think, are generally destined to fail, for several reasons, the first and most important of which is, that no form of coöperation has yet been devised in which each individual is allowed free scope for his personal ambition. Personal ambition always has been and will remain a more powerful incentive to exertion than a desire for the general welfare. The few misplaced drones, who do the loafing and share equally in the profits with the rest, under coöperation are sure to drag the better men down toward their level.

76. The second and almost equally strong reason for failure lies in the remoteness of the reward. The average workman (I don't say all men) cannot look forward to a profit which is six months or a year away. The nice time which they are sure to have to-day, if they take things easily, proves more attractive than hard work, with a possible reward to be shared with others six months later.

77. Other and formidable difficulties in the path of coöperation are, the equitable division of the profits, and the fact that, while workmen are always ready to share the profits, they are neither able nor willing to share the losses. Further than this, in many cases, it is neither right nor just that they should share either in the profits or the losses, since these may be due in great part to causes entirely beyond their influence or control, and to which they do not contribute."

78. Of all the ordinary systems of management in use (in which

no accurate scientific study of the time problem is undertaken, and no carefully measured tasks are assigned to the men which must be accomplished in a given time), the best is the plan fundamentally originated by Mr. Henry R. Towne, and improved and made practical by Mr. F. A. Halsey. This plan is described in papers read by Mr. Towne before this Society in 1886, and by Mr. Halsey in 1891, and has since been criticised and ably defended in a series of articles appearing in the *American Machinist.*

79. The Towne-Halsey plan consists in recording the quickest time in which a job has been done, and fixing this as a standard. If the workman succeeds in doing the job in a shorter time, he is still paid his same wages per hour for the time he works on the job, and in addition is given a premium for having worked faster, consisting of from one-quarter to one-half the difference between the wages earned and the wages originally paid when the job was done in standard time. Mr. Halsey recommends the payment of one-third of the difference as the best premium for most cases. The difference between this system and ordinary piece work is that the workman on piece work gets the whole of the difference between the actual time of a job and the standard time, while under the Towne-Halsey plan he gets only a fraction of this difference.

80. It is not unusual to hear the Towne-Halsey plan referred to as practically the same as piece work. This is far from the truth, for while the difference between the two does not appear to a casual observer to be great, and the general principles of the two seem to be the same, still we all know that success or failure in many cases hinges upon small differences.

81. In the writer's judgment, the Towne-Halsey plan is a great invention, and, like many other great inventions, its value lies in its simplicity.

82. This plan has already been successfully adopted by a large number of establishments, and has resulted in giving higher wages to many workmen, accompanied by a lower labor cost to the employer, and at the same time materially improving their relations by lessening the feeling of antagonism between the two.

83. This system is successful because it diminishes soldiering, and this rests entirely upon the fact that since the workman only receives say one-third of the increase in pay that he would get

under corresponding conditions on piece work, there is not the same temptation for the employer to cut prices.

84. After this system has been in operation for a year or two, if no cuts in prices have been made, the tendency of the men to soldier on that portion of the work which is being done under the system is diminished, although it does not entirely cease. On the other hand, the tendency of the men to soldier on new work which is started, and on such portions as are still done on day work, is even greater under the Towne-Halsey plan than under piece work.

85. To illustrate: Workmen, like the rest of mankind, are more strongly influenced by object lessons than by theories. The effect on men of such an object lesson as the following will be apparent. Suppose that two men are at work by the day and receive the same pay, say 20 cents per hour; Smart and Honest. Each of these men is given a new piece of work which could be done in one hour. Smart does his job in four hours (and it is by no means unusual for men to soldier to this extent). Honest does his in one and one-half hours.

86. Now, when these two jobs start on this basis under the Towne-Halsey plan and are ultimately done in one hour each, Smart receives for his job 20 cents per hour + a premium of $\frac{60}{3}$ = 20 cents = *a total of 40 cents.* Honest receives for his job 20 cents per hour + a premium of $\frac{10}{3}$ = $3\frac{1}{3}$ cents = *a total of $23\frac{1}{3}$ cents.*

87. Most of the men in the shop will follow the example of Smart rather than that of Honest and will "soldier" to the extent of three or four hundred per cent. if allowed to do so.

88. The Towne-Halsey system shares with ordinary piece work then, the greatest evil of the latter, namely, that its very foundation rests upon deceit, and under both of these systems there is necessarily, as we have seen, a great lack of justice and equality in the starting-point of different jobs.

89. Some of the rates will have resulted from records obtained when a first-class man was working close to his maximum speed, while others will be based on the performance of a poor man at one-third or one-quarter speed.

90. The injustice of the very foundation of the system is thus forced upon the workman every day of his life, and no man, however kindly disposed he may be toward his employer, can fail to

resent this and be seriously influenced by it in his work. These systems are, therefore, of necessity slow and irregular in their operation in reducing costs. They drift gradually toward an increased output, but under them the attainment of the maximum output of a first-class man is almost impossible.

91. The writer has seen many jobs successfully nursed in several of our large and well managed establishments under these drifting systems, for a term of ten to fifteen years, at from one-third to one-quarter speed. The workmen, in the meanwhile, apparently enjoyed the confidence of their employers, and in many cases the employers not only suspected the deceit, but felt quite sure of it.

92. The great defect, then, common to all the ordinary systems of management (including the Towne-Halsey system, the best of this class), is that their starting-point, their very foundation, rests upon ignorance and deceit, and that throughout their whole course in the one element which is most vital both to employer and workmen, namely, the speed at which work is done, they are allowed to drift instead of being intelligently directed and controlled.

93. The writer has found, through an experience of twenty years, covering a large variety in manufactures, as well as in the building trades, structural and engineering work, that it is not only practicable but comparatively easy to obtain through a systematic and scientific TIME STUDY, exact information as to how much of any given kind of work either a first-class or an average man can do in a day, and with this information as a foundation, he has over and over again seen the fact demonstrated that workmen of all classes are not only willing, but glad to give up all idea of soldiering, and devote all of their energies to turning out the maximum work possible, providing they are sure of a suitable permanent reward.

94. With accurate time knowledge as a basis, surprisingly large results can be obtained under any scheme of management from day work up; there is no question that even ordinary day work resting upon this foundation will give greater satisfaction than any of the systems in common use, standing as they do upon soldiering as a basis.

95. To many of the readers of this paper both the fundamental objects to be aimed at, namely, HIGH WAGES WITH LOW LABOR COST, and the means advocated by the writer for attaining this end;

namely, ACCURATE TIME STUDY, will appear so theoretical and so far outside of the range of their personal observation and experience that it would seem desirable, before proceeding farther, to give a brief illustration of what has been accomplished in this line.

96. The writer chooses from among a large variety of trades to which these principles have been applied, the yard labor handling raw materials in the works of the Bethlehem Steel Company at South Bethlehem, Pa., not because the results attained there have been greater than in many other instances, but because the case is so elementary that the results are evidently due to no other cause than thorough time study as a basis, followed by the application of a few simple principles with which all of us are familiar.

97. In almost all of the other more complicated cases the large increase in output is due partly to the actual physical changes, either in the machines or small tools and appliances, which a preliminary time study almost always shows to be necessary, so that for purposes of illustration the simple case chosen is the better, although the gain made in the more complicated cases is none the less legitimately due to the system.

98. Up to the spring of the year 1899, all of the materials in the yard of the Bethlehem Steel Company had been handled by gangs of men working by the day, and under the foremanship of men who had themselves formerly worked at similar work as laborers. Their management was about as good as the average of similar work, although it was bad, all of the men being paid the ruling wages of laborers in this section of the country, namely, $1.15 per day, the only means of encouraging or disciplining them being either talking to them or discharging them; occasionally, however, a man was selected from among these men and given a better class of work with slightly higher wages in some of the companies' shops, and this had the effect of slightly stimulating them. From four to six hundred men were employed on this class of work throughout the year.

99. The work of these men consisted mainly of unloading from railway cars and shovelling on to piles, and from these piles again loading as required, the raw materials used in running three blast furnaces and seven large open-hearth furnaces, such as ore of various kinds, varying from fine, gravelly ore to that which comes in large lumps, coke, limestone, special pig, sand, etc., unloading hard and soft coal for boilers, gas-producers, etc., and also for storage and again loading the stored coal as required

for use, loading the pig iron produced at the furnaces for shipment, for storage, and for local use, and handling billets, etc., produced by the rolling mills. The work covered a large variety as laboring work goes, and it was not usual that a man was kept continuously at the same class of work.

100. Before undertaking the management of these men, the writer was informed that they were steady workers, but slow and phlegmatic, and that nothing would induce them to work fast.

101. His first step was to place an intelligent, college-educated man in charge of progress in this line. This man had not before handled this class of labor, although he understood managing workmen. He was not familiar with the methods pursued by the writer, but was soon taught the art of determining how much work a first-class man can do in a day. This was done by timing with a stop watch a first-class man while he was working fast. The best way to do this, in fact almost the only way in which the timing can be done with certainty, is to divide the man's work into its elements and time each element separately. For example, in the case of a man loading pig iron on to a car, the elements should be: Picking up the pig from the ground or pile (time in hundredths of a minute). Walking with it on a level (time per foot walked). Walking with it up an incline to car (time per foot walked). Throwing the pig down (time in hundredths of a minute), or laying it on a pile (time in hundredths of a minute). Walking back empty to get a load (time per foot walked).

102. In case of important elements which were to enter into a number of rates, a large number of observations were taken when practicable on different first-class men, and at different times, and they were averaged.

103. The most difficult elements to time and decide upon in this, as in most cases, are the percentage of the day required for rest, and the time to allow for accidental or unavoidable delays.

104. In the case of the yard labor at Bethlehem, each class of work was studied as above, each element being timed separately, and in addition, a record was kept in many cases of the total amount of work done by the man in a day. The record of the gross work of the man (who is being timed) is, in most cases, not necessary after the observer is skilled in his work. As the Bethlehem time observer was new to this work, the gross time was useful in checking his detailed observations and so gradually educating him and giving him confidence in the new methods.

105. The writer had so many other duties that his personal help was confined to teaching the proper methods and approving the details of the various changes which were in all cases outlined in written reports before being carried out.

106. As soon as a careful study had been made of the time elements entering into one class of work, a single first-class workman was picked out and started on ordinary piece work on this job. His task required him to do between *three and one-half* and *four times* as much work in a day as had been done in the past on an average.

107. Between twelve and thirteen tons of pig iron per man had been carried from a pile on the ground, up an inclined plank, and loaded on to a gondola car by the average pig iron handler while working by the day. The men in doing this work had worked in gangs of from five to twenty men.

108. The man selected from one of these gangs to make the first start under the writer's system was called upon to load on piece-work from forty-five to forty-eight tons (2,240 lbs. each) per day.

109. He regarded this task as an entirely fair one, and earned on an average, from the start, $1.85 per day, which was 60 per cent. more than he had been paid by the day. This man happened to be considerably lighter than the average good workman at this class of work. He weighed about 130 pounds. He proved, however, to be especially well suited to this job, and was kept at it steadily throughout the time that the writer was in Bethlehem, and I believe is still at the same work.

110. Being the first piece work started in the works, it excited considerable opposition, both on the part of the workmen and of several of the leading men in the town, their opposition being based mainly on the old fallacy that if piece work proved successful a great many men would be thrown out of work, and that thereby not only the workmen but the whole town would suffer.

111. One after another of the new men who were started singly on this job were either persuaded or intimidated into giving it up. In many cases they were given other work by those interested in preventing piece work, at wages higher than the ruling wages. In the meantime, however, the first man who started on the work earned steadily $1.85 per day, and this object lesson gradually wore out the concerted opposition, which ceased rather suddenly after about two and one-half months. From this time on there

was no difficulty in getting plenty of good men who were anxious to start on piece work, and the difficulty lay in making with sufficient rapidity the accurate time study of the elements or "unit times" which forms the foundation of this kind of piece work.

112. Throughout the introduction of piece work, when after a thorough time study a new section of the work was started, one man only was put on each new job, and not more than one man was allowed to work at it until he had demonstrated that the task set was a fair one by earning an average of $1.85 per day. After a few sections of the work had been started in this way, the complaint on the part of the better workmen was that they were not allowed to go on to piece work fast enough.

113. It required about two years to transfer practically all of the yard labor from day to piece work. And the larger part of the transfer was made during the last six months of this time.

114. As stated above, the greater part of the time was taken up in studying "unit times," and this time study was greatly delayed by having successively the two leading men who had been trained to the work leave because they were offered much larger salaries elsewhere. The study of "unit times" for the yard labor took practically the time of two trained men for two years. Throughout this time the day and piece workers were under entirely separate and distinct management. The original foremen continued to manage the day work, and day and piece workers were never allowed to work together. Gradually the day work gang was diminished and the piece workers were increased as one section of work after another was transformed from the former to the latter.

115. Two elements which were important to the success of this work should be noted:

116. First, on the morning following each day's work, each workman was given a slip of paper informing him in detail just how much work he had done the day before, and the amount he had earned. Thus enabling him to measure his performance against his earnings while the details were fresh in his mind.

117. Without this there would have been great dissatisfaction among those who failed to climb up to the task asked of them, and many would have gradually fallen off in their performance.

118. Second, whenever it was practicable, each man's work was measured by itself. Only when absolutely necessary was the

work of two men measured up together and the price divided between them, and then care was taken to select two men of as nearly as possible the same capacity.

119. Only on few occasions, and then upon special permission signed by the writer, were more than two men allowed to work on gang work, dividing their earnings between them.

120. Gang work almost invariably results in a falling off in earnings and consequent dissatisfaction.

121. An interesting illustration of the desirability of individual piece work instead of gang work came to our attention at Bethlehem. Several of the best piece workers among the Bethlehem yard laborers were informed by their friends that a much higher price per ton was paid for shovelling ore in another works than the rate given at Bethlehem. After talking the matter over with the writer he advised them to go to the other works, which they accordingly did.

122. In about a month they were all back at work in Bethlehem again, having found that at the other works they were obliged to work with a gang of men instead of on individual piece work, and that the rest of the gang worked so slowly that in spite of the high price paid per ton they earned much less than at Bethlehem.

123. The table on next page gives a summary of the work done by the piece work laborers in handling raw materials, such as ores, anthracite and bituminous coal, coke, pig iron, sand, limestone, cinder, scale, ashes, etc., in the works of the Bethlehem Steel Company, during the year ending April 30, 1901. This work consisted mainly in loading and unloading cars on arrival or departure from the works, and for local transportation, and was done entirely by hand, *i.e.*, without the use of cranes or other machinery.

124. The greater part of the credit for making the accurate time study and actually managing the men on this work, should be given to Mr. A. B. Wadleigh, the writer's assistant in this section at that time.

125. When the writer left the steel works, the Bethlehem piece workers were the finest body of picked laborers that he has ever seen together. They were practically all first-class men because in each case the task which they were called upon to perform was such that only a first-class man could do it. The tasks were all purposely made so severe that not more than one out of five

	Piece Work.	Day Work.
Number of tons (2,240 lbs. per ton) handled on piece work during the year ending April 30, 1901........	$924,040\frac{13}{100}$	
Total cost of handling $924,040\frac{13}{100}$ tons including the piece work wages paid the men, and in addition all incidental day labor used	$30,797.78	
Former cost of handling the same number of tons of similar materials on day work	....	$67,215.47
Net saving in handling $924,040\frac{13}{100}$ tons of materials, effected in one year through substituting piece work for day work	$36,417.69	
Average cost for handling a ton (2,240 lbs.) on piece and day work	$0.033	$0.072
Average earnings per day, per man..................	* $1.88	$1.15
Average number of tons handled per day per man	57	16

The piece workers handled on an average $3\frac{56}{100}$ times as many tons per man per day as the day workers.

* It was our intention to fix piece work rates which should enable first-class workmen to average about 60 per cent. more than they had been earning on day work, namely $1.85 per day. A year's average shows them to have earned $1.88 per day, or three cents per man per day more than we expected. An error of $1\frac{6}{10}$ per cent.

laborers (perhaps even a smaller percentage than this) could keep up.

126. It was clearly understood by each newcomer as he went to work that unless he was able to average at least $1.85 per day he would have to make way for another man who could do so. As a result, first-class men from all over that part of the country, who were in most cases earning from $1.05 to $1.15 per day, were anxious to try their hands at earning $1.85 per day. If they succeeded they were naturally contented, and if they failed they left, sorry that they were unable to maintain the proper pace, but with no hard feelings either toward the system or the management. Throughout the time that the writer was there, labor was as scarce and as difficult to get as it ever has been in the history of this country, and yet there was always a surplus of first-class men ready to leave other jobs and try their hand at Bethlehem piece work.

127. Perhaps the most notable difference between these men and ordinary piece workers lay in their changed mental attitude toward their employers and their work, and in the total absence

of soldiering on their part. The ordinary piece worker would have spent a considerable part of his time in deciding just how much his employer would allow him to earn without cutting prices and in then trying to come as close as possible to this figure, while carefully guarding each job so as to keep the management from finding out how fast it really could be done. These men, however, were faced with a new but very simple and straightforward proposition, namely, am I a first-class laborer or not? Each man felt that if he belonged in the first class all he had to do was to work at his best and he would be paid sixty per cent. more than he had been paid in the past. Each new piece work price was accepted by the men without question. They never bargained over nor complained about rates, and there was no occasion to do so, since they were all equally fair, and called for almost exactly the same amount of work and fatigue per dollar of wages.

128. A careful inquiry into the condition of these men when away from work developed the fact that out of the whole gang, only two were said to be drinking men. This does not, of course, imply that many of them did not take an occasional drink. The fact is that a steady drinker would find it almost impossible to keep up with the pace which was set, so that they were practically all sober. Many if not most of them were saving money, and they all lived better than they had before. The results attained under this system were most satisfactory both to employer and workmen, and show in a convincing way the possibility of uniting high wages with a low labor cost.

129. This is virtually a labor union of first-class men, who are united together to secure the extra high wages, which belong to them by right and which in this case are begrudged them by none, and which will be theirs through dull times as well as periods of activity. Such a union commands the unqualified admiration and respect of all classes of the community; the respect equally of workmen, employers, political economists, and philanthropists. There are no dues for membership, since all of the expenses are paid by the company. The employers act as the officers of the Union, to enforce its rules and keep its records, since the interests of the company are identical and bound up with those of the men. It is never necessary to plead with, or persuade men to join this Union, since the employers themselves organize it free of cost; the best workmen in the community are always anxious

to belong to it. The feature most to be regretted about it is that the membership is limited.

130. The words " labor union " are, however, unfortunately so closely associated in the minds of most people with the idea of disagreement and strife between the employers and men, that it seems almost incongruous to apply them to this case.

131. Is not this, however, the ideal " labor union," with character and special ability of a high order as the only qualifications for membership.

132. It is a curious fact that with the people to whom the writer has described this system, the first feeling, particularly among those more philanthropically inclined, is one of pity for the inferior workmen who lost their jobs in order to make way for the first-class men. This sympathy is entirely misplaced. There was such a demand for labor at the time, that no workman was obliged to be out of work for more than a day or two, and so the poor workmen were practically as well off as ever. The feeling, instead of being one of pity for the inferior workmen, should be one of congratulation and rejoicing that many first-class men —who through unfortunate circumstances had never had the opportunity of proving their worth—at last were given the chance to earn high wages and become prosperous.

133. What the writer wishes particularly to emphasize is that this whole system rests upon an accurate and scientific study of " unit times," which is by far the most important element in modern management. With it, greater and more permanent results can be attained even under ordinary day work or piece work than can be reached under any of the more elaborate systems without it.

134. In 1895 the writer read a paper before this Society entitled " A Piece Rate System." His chief object in writing it was to advocate the study of " unit times " as the foundation of good management. Unfortunately, he at the same time described the " Differential Rate " system of piece work, which had been introduced by him in the Midvale Steel Works. Although he called attention to the fact that the latter was entirely of secondary importance, the differential rate was widely discussed in the journals of this country and abroad while practically nothing was said about the study of " unit times." Thirteen members of this Society discussed the piece rate system at length, and only two briefly referred to the study of the " unit times."

135. The writer most sincerely trusts that his leading object in writing this paper will not be overlooked, and that SCIENTIFIC TIME STUDY will receive the attention which it merits. Bearing in mind the Bethlehem yard labor as an illustration of the application of the study of unit times as the foundation of success in management, the following would seem to him a fair comparison of the older methods with the more modern plan:

136. For each job there is the quickest time in which it can be done by a first-class man. This time may be called the "quickest time," or the "standard time" for the job.

137. Under all the ordinary systems, this "quickest time" is more or less completely shrouded in mist. In most cases, however, the workman is nearer to it and sees it more clearly than the employer.

138. Under ordinary piecework the management watch every indication given them by the workmen as to what the "quickest time" is for each job, and endeavor continually to force the men toward this "standard time," while the workmen constantly use every effort to prevent this from being done and to lead the management in the wrong direction. In spite of this conflict, however, the "standard time" is gradually approached.

139. Under the Towne-Halsey* plan the management gives up all *direct* effort to reach this "quickest time," but offers mild inducements to the workmen to do so, and turns over the whole enterprise to them. The workmen, peacefully as far as the management is concerned but with considerable pulling and hauling among themselves, and without the assistance of a trained guiding hand, drift gradually and slowly in the direction of the "standard time," but rarely approach it closely.

140. With accurate time study as a basis, the "quickest time" for each job is at all times in plain sight of both employers and workmen, and is reached with accuracy, precision and speed, both sides pulling hard in the same direction under the uniform simple and just agreement that whenever a first-class man works at his best he will receive from 30 to 100 per cent. more than the average of his trade.

141. Probably a majority of the attempts that are made to radically change the organization of manufacturing companies result in a loss of money to the company, failure to bring about the

* For further criticism of the Towne-Halsey plan, see Mr. Halsey's remarks at the end of the paper and the writer's answer to same.

change sought for, and a return to practically the original organization. The reason for this being that there are but few employers who look upon management as an art, and that they go at a difficult task without either having understood or appreciated the time required for organization or its cost, the troubles to be met with or the obstacles to be overcome, and without having studied the means to be employed in doing so.

142. Before starting to make any changes in the organization of a company, the following matters should be carefully considered: First, the importance of choosing the general type of management best suited to the particular case. Second, that in all cases money must be spent, and in many cases a great deal of money, before the changes are completed which result in lowering cost. Third, that it takes time to reach any result worth aiming at. Fourth, the importance of making changes in their proper order, and that unless the right steps are taken, and taken in their proper sequence, there is great danger from deterioration in the quality of the output and from serious troubles with the workmen, often resulting in strikes.

143. As to the type of management to be ultimately aimed at, before any changes whatever are made, it is necessary, or at least highly desirable, that the most careful consideration should be given to the type to be chosen; and once a scheme is decided upon it should be carried forward step by step without wavering or retrograding. Workmen will tolerate and even come to have great respect for one change after another made in logical sequence and according to a consistent plan. It is most demoralizing, however, to have to recall a step once taken, whatever may be the cause, and it makes any further changes doubly difficult.

144. The choice must be made between some of the types of management in common use, which the writer feels are properly designated by the work "drifting," and the more modern and scientific management based on an accurate knowledge of how long it should take to do the work. If, as is frequently the case, the managers of an enterprise find themselves so overwhelmed with other departments of the business that they can give but little thought to the management of the shop, then some one of the various "drifting" schemes should be adopted; and of these the writer believes the Towne-Halsey plan to be the best, since it drifts safely and peacefully though slowly in the right direction; yet under it the best results can never be reached. The

fact, however, that managers are in this way overwhelmed by their work is the best proof that there is something radically wrong with the plan of their organization and in self defence they should take immediate steps toward a more thorough study of the art.

145. It is not at all generally realized that whatever system may be used,—providing a business is complex in its nature—the building up of an efficient organization is necessarily slow and sometimes very expensive. Almost all of the directors of manufacturing companies appreciate the economy of a thoroughly modern, up-to-date and efficient plant and are willing to pay for it. Very few of them, however, realize that the best organization, whatever its cost may be, is in many cases even more important than the plant; nor do they clearly realize that no kind of an efficient organizaton can be built up without spending money. The spending of money for good machinery appeals to them because they can see machines after they are bought; but putting money into anything so invisible, intangible, and to the average man so indefinite, as an organization seems almost like throwing it away.

146. There is no question that when the work to be done is at all complicated, a good organization with a poor plant will give better results than the best plant with a poor organization. One of the most successful manufacturers in this country was asked recently by a number of financiers whether he thought that the difference between one style of organization and another amounted to much providing the company had an up-to-date plant properly located. His answer was, "If I had to choose now between abandoning my present organization and burning down all of my plants which have cost me millions, I should choose the latter. My plants could be rebuilt in a short while with borrowed money, but I could hardly replace my organization in a generation."

147. Modern engineering can almost be called an exact science; each year removes it further from guess work and from rule of thumb methods and establishes it more firmly upon the foundation of fixed principles.

148. The writer feels that management is also destined to become more of an art, and that many of the elements which are now believed to be outside the field of exact knowledge will soon be standardized, tabulated, accepted and used, as are now the many elements of engineering. Management will be studied as an art

and will rest upon well recognized, clearly defined and fixed principles instead of depending upon more or less hazy ideas received from a limited observation of the few organizations with which the individual may have come in contact. There will, of course, be various successful types, and the application of the underlying principles must be modified to suit each particular case. The writer has already indicated that he thinks the first object in management is to unite high wages with a low labor cost. He believes that this object can be most easily attained by the application of the following principles:

First.—A LARGE DAILY TASK.

149. Each man in the establishment, high or low, should daily have a clearly defined task laid out before him. This task should not in the least degree be vague nor indefinite, but should be circumscribed carefully and completely, and should not be easy to accomplish.

Second.—STANDARD CONDITIONS.

150. Each man's task should call for a full day's work, and at the same time the workman should be given such conditions and appliances as will enable him to accomplish his task with certainty.

Third.—HIGH PAY FOR SUCCESS.

151. He should be sure of large pay when he accomplishes his task.

Fourth.—LOSS IN CASE OF FAILURE.

152. When he fails he should be sure that sooner or later he will be the loser by it.

153. When an establishment has reached an advanced state of organization, in many cases a fifth element should be added, namely: the task should be made so difficult that it can only be accomplished by a first-class man.

154. There is nothing new nor startling about any of these principles and yet it will be difficult to find a shop in which they are not daily violated over and over again. They call, however, for a greater departure from the ordinary types of organization than would at first appear. In the case, for instance, of a machine shop doing miscellaneous work, in order to assign daily to each man a carefully measured task, a special planning department is re-

quired to lay out all of the work at least one day ahead. All orders must be given to the men in detail in writing; and in order to lay out the next day's work and plan the entire progress of work through the shop, daily returns must be made by the men to the planning department in writing, showing just what has been done. Before each casting or forging arrives in the shop the exact route which it is to take from machine to machine should be laid out. An instruction card for each operation must be written out stating in detail just how each operation on every piece of work is to be done and the time required to do it, the drawing number, any special tools, jigs, or appliances required, etc. Before the four principles above referred to can be successfully applied it is also necessary in most shops to make important physical changes. All of the small details in the shop, which are usually regarded as of little importance and are left to be regulated according to the individual taste of the workman, or, at best, of the foreman, must be thoroughly and carefully standardized; such details, for instance, as the care and tightening of the belts; the exact shape and quality of each cutting tool; the establishment of a complete tool room from which properly ground tools, as well as jigs, templets, drawings, etc., are issued under a good check system, etc.; and as a matter of importance (in fact, as the foundation of modern management) an accurate study of "unit times" must be made by one or more men connected with the planning department, and each machine tool must be standardized and a table or slide rule constructed for it showing how to run it to the best advantage.

155. At first view the running of a planning department, together with the other innovations, would appear to involve a large amount of additional work and expense, and the most natural question would be is whether the increased efficiency of the shop more than offsets this outlay. It must be borne in mind, however, that, with the exception of the study of unit times, there is hardly a single item of work done in the planning department which is not already being done in the shop. Establishing a planning department merely concentrates the planning and much other brainwork in a few men especially fitted for their task and trained in their especial lines, instead of having it done, as heretofore, in most cases by high priced mechanics, well fitted to work at their trades but poorly trained for work more or less clerical in its nature.

156. There is a close analogy between the methods of modern engineering and this type of management. Engineering now centres in the drafting room as modern management does in the planning department. The old style engineering had all the appearance of simplicity and economy, while modern engineering has all the appearance of complication and extravagance, with its multitude of drawings; and the amount of study and work which is put into each detail; and its corps of draftsmen, all of whom would be sneered at by the old engineer as "non-producers." For the same reason, modern management, with its minute time study and a managing department in which each operation is carefully planned, with its many written orders and its apparent red tape, looks like a waste of money; while the ordinary management in which the planning is mainly done by the workmen themselves with the help of one or two foremen, seems simple and economical in the extreme. The writer, however, while still a young man, had all lingering doubt as to the value of a drafting room dispelled by seeing the chief engineer, the foreman of the machine shop, the foreman of the foundry and one or two workmen, in one of our large and successful engineering establishments of the old school, stand over the cylinder of an engine which was being built, with chalk and dividers, and discuss for more than an hour the proper size and location of the studs for fastening on the cylinder head. This was simplicity, but not economy. About the same time he became thoroughly convinced of the necessity and economy of a planning department with time study, and with written instruction cards and returns. He saw over and over again a workman shut down his machine and hunt up the foreman to inquire, perhaps, what work to put into his machine next, and then chase around the shop to find it or to have a special tool or templet looked up or made. He saw workmen carefully nursing their jobs by the hour and doing next to nothing to avoid making a record, and he was even more forcibly convinced of the necessity for a change while he was still working as a machinist by being ordered by the other men to slow down to half speed under penalty of being thrown over the fence.

157. No one now doubts the economy of the drafting room, and the writer predicts that twenty years from now no one will doubt the economy and necessity of the study of unit times and of the planning department.

158. Another point of analogy between modern engineering

and modern management lies in the fact that modern engineering proceeds with comparative certainty to the design and construction of a machine or structure of the maximum efficiency with the minimum weight and cost of materials, while the old style engineering at best only approximated these results and then only after a series of breakdowns, involving the practical reconstruction of the machine and the lapse of a long period of time. The ordinary system of management, owing to the lack of exact information and precise methods, can only approximate to the desired standard of high wages accompanied by low labor cost and then only slowly, with marked irregularity in results, with continued opposition, and, in many cases, with danger from strikes. Modern management, on the other hand, proceeds slowly at first, but with directness and precision, step by step, and, after the first few object lessons, almost without opposition on the part of the men, to high wages and low labor cost; and what is of great importance, it assigns wages to the men which are uniformly fair. They are not demoralized, and their sense of justice offended by receiving wages which are sometimes too low and at other times entirely too high. One of its marked advantages lies in its freedom from strikes. The writer has never been opposed by a strike, although he has been engaged for a great part of his time since 1883 in introducing this type of management in different parts of the country and in a great variety of industries. The only case of which the writer can think in which a strike under this system might be unavoidable would be that in which most of the employees were members of a labor union, and of a union whose rules were so inflexible and whose members were so stubborn that they were unwilling to try any other system, even though it assured them larger wages than their own. The writer has seen, however, several times after the introduction of this system, the members of labor unions who were working under it leave the union in large numbers because they found that they could do better under the operation of the system than under the laws of the union.

159. There is no question that the average individual accomplishes the most when he either gives himself, or someone else assigns him, a definite task, namely, a given amount of work which he must do within a given time; and the more elementary the mind and character of the individual the more necessary does it become that each task shall extend over a short period of time only. No

school teacher would think of telling children in a general way to study a certain book or subject. It is practically universal to assign each day a definite lesson beginning on one specified page and line and ending on another; and the best progress is made when the conditions are such that a definite study hour or period can be assigned in which the lesson must be learned. Most of us remain, through a great part of our lives, in this respect, grown-up children, and do our best only under pressure of a task of comparatively short duration.

160. Another and perhaps equally great advantage of assigning a daily task as against ordinary piece work lies in the fact that the success of a good workman or the failure of a poor one is thereby daily and prominently called to the attention of the management. Many a poor workman might be willing to go along in a slipshod way under ordinary piece work, careless as to whether he fell off a little in his output or not. Very few of them, however, would be willing to record a daily failure to accomplish their task even if they were allowed to do so by their foreman; and also since on ordinary piece work the price alone is specified without limiting the time which the job is to take, a quite large falling off in output can in many cases occur without coming to the attention of the management at all. It is for these reasons that the writer has above indicated "A Large Daily Task" for each man as the first of four principles which should be included in the best type of management.

161. It is evident, however, that it is useless to assign a task unless at the same time adequate measures are taken to enforce its accomplishment. As Artemus Ward says, "I can call the spirits from the windy deep, but damn 'em they won't come!" It is to compel the completion of the daily task then that two of the other principles are required, namely, "High Pay for Success" and "Loss in Case of Failure." The advantage of Mr. Gantt's system of "Task Work with a Bonus," and the writer's "Differential Rate Piece Work" over the other systems lies in the fact that with each of these the men automatically and daily receive either an extra reward in case of complete success, or a distinct loss in case they fall off even a little.

162. The four principles above referred to can be successfully applied either under day work, piece work, "Task Work with a Bonus," or "Differential Rate Piece Work," and each of these systems has its own especial conditions under which it is to be pre-

ferred to either of the other three. In no case, however, should an attempt be made to apply these principles unless an accurate and thorough time study has perviously been made of every item entering into the day's task.

163. They should be applied under day work only when a number of miscellaneous jobs have to be done day after day, none of which can occupy the entire time of a man throughout the whole of a day and when the time required to do each of these small jobs is likely to vary somewhat each day. In this case a number of these jobs can be grouped into a daily task which should be assigned, if practicable, to one man, possibly even to two or three, but rarely to a gang of men of any size. To illustrate: In a small boiler house in which there is no storage room for coal, the work of wheeling the coal to the fireman, wheeling out the ashes, helping clean fires and keeping the boiler room and the outside of the boilers clean could be made into the daily task for a man, and if these items did not sum up into a full day's work, on the average, other duties could be added until a proper task was assured. Or, the various details of sweeping, cleaning and keeping a certain section of a shop floor, windows, machines, etc., in order can be united to form a task. Or, in a small factory which turns out a uniform product and in uniform quantities day after day, supplying raw materals to certain parts of the factory and removing finished product from others may be coupled with other definite duties to form a task. The task should call for a large day's work, and the man should be paid more than the usual day's pay so that the position will be sought for by first-class, ambitious men. Clerical work can very properly be done by the task in this way, although when there is enough of it, piece work at so much per entry is to be preferred. In all cases a clear cut, definite inspection of the task is desirable at least once a day and sometimes twice. When a shop is not running at night, a good time for this inspection is at seven o'clock in the morning, for instance. The inspector should daily sign a printed card, stating that he has inspected the work done by ———, and enumerating the various items of the task. The card should state that the workman has satisfactorily performed his task, except the following items which should be enumerated in detail.

164. When men are working on task work by the day, they should be made to start to work at the regular starting hour. They

should, however, have no regular time for leaving. As soon as the task is finished they should be allowed to go home; and, on the other hand, they should be made to stay at work until their task is done, even if it lasts into the night, no deduction being made for shorter hours nor extra pay allowed for overtime. It is both inhuman and unwise to ask a man, working on task work, to stay in the shop after his task is finished "to maintain the discipline of the shop," as is frequently done. It only tends to make men eye servants.

165. An amusing instance of the value of task work with freedom to leave when the task is done was given the writer by his friend, Mr. Chas. D. Rogers, for many years superintendent of the American Screw Works, of Providence, R. I., one of the greatest mechanical geniuses and most resourceful managers that this country has produced, but a man who, owing to his great modesty, has never been fully appreciated outside of those who know him well. Mr. Rogers tried several modifications of day and piece work in an unsuccessful endeavor to get the children who were engaged in sorting over the very small screws to do a fair day's work. He finally met with great success by assigning to each child a fair day's task and allowing him to go home and play as soon as his task was done. Each child's play time was his own and highly prized while the greater part of his wages went to his parents.

166. Piece work embodying the task idea can be used to advantage when there is enough work of the same general character to keep a number of men busy regularly; such work, for instance, as the Bethlehem yard labor above described, or the work of bicycle ball inspection referred to later on. In piece work of this class the task idea should always be maintained by keeping it clearly before each man that his average daily earnings must amount to a given high sum (as in the case of the Bethlehem laborers, $1.85 per day), and that failure to average this amount will surely result in his being laid off. It must be remembered that on plain piece work the less competent workmen will always bring what influence and pressure they can to cause the best men to slow down towards their level and that the task idea is needed to counteract this influence. Where the labor market is large enough to secure in a reasonable time enough strictly first-class men, the piece work rates should be fixed on such a basis that only a first-class man working at his best can earn the average amount called for. This

figure should be, in the case of first-class men as stated above, from 30 per cent. to 100 per cent. beyond the wages usually paid. The task idea is emphasized with this style of piece work by two things—the high wages and the laying off, after a reasonable trial, of incompetent men; and for the success of the system, the number of men employed on practically the same class of work should be large enough for the workmen quite often to have the object lesson of seeing men laid off for failing to earn high wages and others substituted in their places.

167. There are comparatively few machine shops, or even manufacturing establishments, in which the work is so uniform in its nature as to employ enough men on the same grade of work and in sufficiently close contact to one another to render piece work preferable to the other systems. In the great majority of cases the work is so miscellaneous in its nature as to call for the employment of workmen varying greatly in their natural ability and attainments, all the way, for instance, from the ordinary laborer, through the trained laborer, helper, rough machinist, fitter, machine hand, to the highly skilled special or all-round mechanic; and while in a large establishment there may be often enough men of the same grade to warrant the adoption of piece work with the task idea, yet, even in this case, they are generally so scattered in different parts of the shop that laying off one of their number for incompetence does not reach the others with sufficient force to impress them with the necessity of keeping up with their task.

168. It is evident then that, in the great majority of cases, the four leading principles in management can be best applied through either "Task Work with a Bonus" or the "Differential Rate System," in spite of the slight additional clerical work and the increased difficulty in planning ahead incident to these systems. Three of these principles, namely, "A Large Daily Task," "High Pay for Success," and "Loss in Case of Failure" form the very essence of both of these systems and act as a daily stimulant for the men, and the fourth element is a necessary preliminary, since without having first thoroughly standardized all of the conditions surrounding the work, neither of the two plans can be successfully applied.

169. In many cases the greatest good resulting from the application of these systems is the indirect gain which comes from the enforced standardization of all details and conditions, large and small, surrounding the work. All of the ordinary systems can be

and are almost always applied without adopting and maintaining thorough shop standards. But the Task idea can not be carried out without them.

170. The "Differential Rate Piece Work" is rather simpler in its application and is the more forceful of the two. It should be used wherever it is practicable, but in no case until after all the accompanying conditions have been perfected and completely standardized and a thorough time study has been made of all of the elements of the work. This system is particularly useful where the same kind of work is repeated day after day, and also whenever the maximum possible output is desired, which is almost always the case in the operation of expensive machinery or of a plant occupying valuable ground or a large building. It is more forceful than "Task Work with a Bonus" because it not only pulls the man up from the top but pushes him equally hard from the bottom. Both of these systems give the workman a large extra reward when he accomplishes his full task within the given time. With the differential rate, if for any reason he fails to do his full task, he not only loses the large extra premium which is paid for complete success, but in addition he suffers the direct loss of the piece price for each piece by which he falls short. Failure under the "Task with a Bonus" system involves a corresponding loss of the extra premium or bonus, but the workman, since he is paid a given price per hour, receives his ordinary day's pay in case of failure and suffers no additional loss beyond that of the extra premium whether he may have fallen short of the task to the extent of one piece or a dozen.

171. In principle, these two systems appear to be almost identical, yet this small difference, the slightly milder nature of "Task Work with a Bonus," is sufficient to render it much more flexible and therefore applicable to a large number of cases in which the "differential rate" cannot be used. "Task Work with a Bonus" was invented by Mr. H. L. Gantt while he was assisting the writer in organizing the Bethlehem Steel Company. The possibilities of his system were immediately recognized by all of the leading men engaged on the work, and long before it would have been practicable to use the "Differential Rate," work was started under this plan. It was successful from the start, and steadily grew in volume and in favor, and to-day is more extensively used there than ever before.

172. Mr. Gantt's system is especially useful during the difficult

and delicate period of transition from the slow pace of ordinary day work to the high speed which is the leading characteristic of good management. During this period of transition in the past, a time was always reached when a sudden long leap was taken from improved day work to some form of piece work; and in making this jump many good men inevitably fell and were lost from the procession. Mr. Gantt's system bridges over this difficult stretch and enables the workman to go smoothly and with gradually accelerating speed from the slower pace of improved day work to the high speed of the new system.

173. It does not appear that Mr. Gantt has recognized the full advantages to be derived through the proper application of his system during this period of transition, at any rate he has failed to point them out in his paper and to call attention to the best method of applying his plan in such cases.

174. No workman can be expected to do a piece of work the first time as fast as he will later. It should also be recognized that it takes a certain time for men who have worked at the ordinary slow rate of speed to change to high speed. Mr. Gantt's plan can be adapted to meet both of these conditions by allowing the workman to take a longer time to do the job at first and yet earn his bonus; and later compelling him to finish the job in the quickest time in order to get the premium. In all cases it is of the utmost importance that each instruction card should state the *quickest time* in which the workman will ultimately be called upon to do the work. There will then be no temptation for the man to soldier since he will see that the management know accurately how fast the work can be done.

175. There is also a large class of work in addition to that of the period of transition to which "Task Work with a Bonus" is especially adapted. The higher pressure of the differential rate is the stimulant required by the workman to maintain a high rate of speed and secure high wages while he has the steady swing that belongs to work which is repeated over and over again. When, however, the work is of such variety that each day presents an entirely new task, the pressure of the "differential rate" is sometimes too severe. The chances of failing to quite reach the task are greater in this class of work than in routine work; and in many such cases it is better, owing to the increased difficulties, that the workman should feel sure at least of his regular day's rate, which is secured him by Mr. Gantt's system in case he falls

short of the full task. There is still another case of quite frequent occurrence in which the flexibility of Mr. Gantt's plan makes it the most desirable. In many establishments, particularly those doing an engineering business of considerable variety or engaged in constructing and erecting miscellaneous machinery, it is necessary to employ continuously a number of especially skilful and high-priced mechanics. The particular work for which these men are wanted comes, however, in many cases, at irregular intervals, and there are frequently quite long waits between their especial jobs. During such periods these men must be provided with work which is ordinarily done by less efficient, lower-priced men, and if a proper piece price has been fixed on this work it would naturally be a price suited to the less skilful men, and therefore too low for the men in question. The alternative is presented of trying to compel these especially skilled men to work for a lower price than they should receive, or of fixing a special higher piece price for the work. Fixing two prices for the same piece of work, one for the man who usually does it and a higher price for the higher grade man, always causes the greatest feeling of injustice and dissatisfaction in the man who is discriminated against. With Mr. Gantt's plan, the less skilled workman would recognize the justice of paying his more experienced companion regularly a higher rate of wages by the day, yet when they were both working on the same kind of work each man would receive the same extra bonus for doing the full day's task. Thus, with Mr. Gantt's system, the total day's pay of the higher classed man would be greater than that of the less skilled man, even when on the same work, and the latter would not begrudge it to him. We may say that the difference is one of sentiment, yet sentiment plays an important part in all of our lives; and sentiment is particularly strong in the workman when he believes a direct injustice is being done him.

176. Mr. James M. Dodge, our distinguished president, has invented an ingenious system of piece work which is adapted to meet this very case, and which has especial advantages not possessed by any of the other plans. As he is to present a paper to the Society upon this subject, the writer will not trespass upon his preserves.

177. It is clear, then, that in carrying out the task idea after the required knowledge has been obtained through a study of "unit times," each of the four systems, "Day Work," "Straight Piece

Work," "Task Work with a Bonus," and "Differential Piece Work," has its especial field of usefulness, and that in every large establishment doing a variety of work all four of these plans can and should be used at the same time. Three of these systems were in use at the Bethlehem Steel Company when the writer left there, and the fourth would have soon been started if he had remained.

178. Before leaving this part of the paper which has been devoted to pointing out the value of the "Daily Task" in management, it would seem desirable to give an illustration of the value of the "Differential Rate," and also of the desirability of making each task as simple and short as practicable.

179. The writer quotes as follows from a paper entitled "A Piece Rate System," read by him before this Society in 1895:

180. The first case in which a differential rate was applied during the year 1884, furnishes a good illustration of what can be accomplished by it. A standard steel forging, many thousands of which are used each year, had for several years been turned at the rate of from four to five per day under the ordinary system of piece work, 50 cents per piece being the price paid for the work. After analyzing the job, and determining the shortest time required to do each of the elementary operations of which it was composed, and then summing up the total, the writer became convinced that it was possible to turn ten pieces a day. To finish the forgings at this rate, however, the machinists were obliged to work at their maximum pace from morning to night, and the lathes were run as fast as the tools would allow, and under a heavy feed. (Ordinary tempered tools 1 inch by 1½ inch made of carbon tool steel, were used for this work.)

181. It will be appreciated that this was a big day's work, both for men and machines, when it is understood that it involved removing, with a single 16-inch lathe, having two saddles, an average of more than 800 lbs. of steel chips in ten hours. In place of the 50 cent rate, that they had been paid before, they were given 35 cents per piece when they turned them at the speed of 10 per day, and when they produced less than ten, they received only 25 cents per piece.

182. It took considerable trouble to induce the men to turn at this high speed, since they did not at first fully appreciate that it was the intention of the firm to allow them to earn permanently at the rate of $3.50 per day. But from the day they first turned ten pieces to the present time, a period of more than ten years, the men who understood their work have scarcely failed a single day to turn at this rate. Throughout that time until the beginning of the recent fall in the scale of wages throughout the country, the rate was not cut.

183. During this whole period, the competitors of the company never succeeded in averaging over half of this production per lathe, although they knew and even saw what was being done at Midvale. They, however, did not allow their men to earn over from $2.00 to $2.50 per day, and so never even approached the maximum output.

184. The following table will show the economy of paying high wages under the differential rate in doing the above job:

COST OF PRODUCTION PER LATHE PER DAY.

Ordinary System of Piecework.		Differential Rate System.	
Man's wages	$2.50	Man's wages	$3.50
Machine cost	3.37	Machine cost	3.37
Total cost per day	5.87	Total cost per day	6.87
5 pieces produced; Cost per piece.	$1.17	10 pieces produced; Cost per piece.	$0.69

185. The above result was mostly though not entirely due to the differential rate. The superior system of managing all of the small details of the shop counted for considerable.

186. The exceedingly dull times that began in July, 1893, and were accompanied by a great fall in prices, rendered it necessary to lower the wages of machinists throughout the country. The wages of the men in the Midvale Steel Works were reduced at this time, and the change was accepted by them as fair and just.

187. Throughout the works, however, the principle of the differential rate was maintained, and was, and is still, fully appreciated by both the management and men. Through some error at the time of the general reduction of wages in 1893, the differential rate on the particular job above referred to was removed, and a straight piece-work rate of 25 cents per piece was substituted for it. The result of abandoning the differential proved to be the best possible demonstration of its value. Under straight piece work, the output immediately fell to between six and eight pieces per day, and remained at this figure for several years, although under the differential rate it had held throughout a long term of years steadily at ten per day.

188. When work is to be repeated many times, the time study should be minute and exact. Each job should be carefully subdivided into its elementary operations, and each of these "unit times" should receive the most thorough time study.

189. In fixing the times for the tasks, and the piece-work rates in jobs of this class, the job should be subdivided into a number of divisions, and a separate time and price assigned to each division rather than to assign a single time and price for the whole job. This for several reasons, the most important of which is that the average workman, in order to maintain a rapid pace, should be given the opportunity of measuring his performance against the task set him at frequent intervals. Many men are incapable of

looking very far ahead, but if they see a definite opportunity of earning so many cents by working hard for so many minutes, they will avail themselves of it.

190. As an illustration, the steel tires used on car wheels and locomotives were originally turned in the Midvale Steel Works on piece work, a single piece-work rate being paid for all of the work which could be done on a tire at a single setting. A fixed price was paid for this work, whether there was much or little metal to be removed, and on the average this price was fair to the men. The apparent advantage of fixing a fair average rate was, that it made rate-fixing exceedingly simple, and saved clerk work in the time, cost and record keeping.

191. A careful time study, however, convinced the writer that for the reasons given above most of the men failed to do their best. In place of the single rate and time for all of the work done at a setting, the writer subdivided tire-turning into a number of short operations, and fixed a proper time and price, varying for each small job, according to the amount of metal to be removed, and the hardness and diameter of the tire. The effect of this subdivision was to increase the output, with the same men, methods, and machines, at least thirty-three per cent.

192. As an illustration of the minuteness of this subdivision, an instruction card similar to the one used is reproduced on the next page. (This card should be about 7 inches long by 4½ inches wide.)

193. The cost of the additional clerk work involved in this change was so insignificant that it practically did not affect the problem. This principle of short tasks in tire turning was introduced by the writer in the Midvale Steel Works in 1883 and is still in full use there, having survived the test of twenty years' trial with a change of management.

194. In another establishment a differential rate was applied to tire turning, with operations subdivided in this way, by adding fifteen per cent. to the pay of each tire turner whenever his daily or weekly piece work earnings passed a given figure.

195. Another illustration of the application of this principle of measuring a man's performance against a given task at frequent intervals to an entirely different line of work may be of interest. For this purpose the writer chooses the manufacture of bicycle balls in the works of the Symonds Rolling Machine Company, in Fitchburg, Mass. All of the work done in this factory was sub-

Machine shop . . . .

Order for . . . . Tires . . . .

Do work on Tire No . . . .

as follows and per blue print . . . .

	Templet.	Size to be cut to.	Depth of cut.	Driving belt.	Feed.	Rate.	Time this operation should take.
Surface to be machined							
Set tire on machine ready to turn							
Rough face front edge							
Finish face front edge							
Rough bore front							
Finish bore front							
Rough face front I. S. C.							
Cut out filled							
Rough bore front I. S. F.							
Rough face back edge							
Finish face back edge							
Finish bore back							
Rough bore back							
Rough face back I. S. F							
Cut out filled							
Cut recess							
Rough turn thread							
Finish turn thread							
Rough turn flange							
Finish turn flange							
Clean fillet of flange							
Remove tire from machine and clean face plate							

jected to an accurate time study, and then was changed from day to piece work through the assistance of functional foremanship, etc. The particular operation to be described, however, is that of inspecting bicycle balls before they were finally boxed for shipment. Many millions of these balls were inspected annually. When the writer undertook to systematize this work, the factory had been running for eight or ten years on ordinary day work, so that the various employees were "old hands," and skilled at their jobs. The work of inspection was done entirely by girls—about one hundred and twenty being employed at it—all on day work.

196. This work consisted briefly in placing a row of small polished steel balls on the back of the left hand, in the crease between two of the fingers pressed together, and while they were rolled over and over, with the aid of a magnet held in the right hand, they were minutely examined in a strong light, and the defective balls picked out and thrown into especial boxes. Four kinds of defects were looked for—dented, soft, scratched, and fire cracked—and they were mostly so minute as to be invisible to an eye not especially trained to this work. It required the closest attention and concentration. The girls had worked on day work for years, ten and one-half hours per day, with a Saturday half-holiday.

197. The first move before in any way stimulating them toward a larger output was to insure against a falling off in quality. This was accomplished through over-inspection. Four of the most trustworthy girls were given each a lot of balls which had been examined the day before by one of the regular inspectors. The number identifying the lot having been changed by the foreman so that none of the over-inspectors knew whose work they were examining. In addition, one of the lots inspected by the four over-inspectors was examined on the following day by the chief inspector, selected on account of her accuracy and integrity.

198. An effective expedient was adopted for checking the honesty and accuracy of the over-inspection. Every two or three days a lot of balls was especially prepared by the foreman, who counted out a definite number of perfect balls, and added a recorded number of defective balls of each kind. The inspectors had no means of distinguishing this lot from the regular commercial lots. And in this way all temptation to slight their work or make false returns was removed.

199. After insuring in this way against deterioration in quality,

effective means were at once adopted to increase the output. Improved day work was substituted for the old slipshod method. An accurate daily record, both as to quantity and quality, was kept for each inspector. In a comparatively short time this enabled the foreman to stir the ambition of all the inspectors by increasing the wages of those who turned out a large quantity and good quality, at the same time lowering the pay of those who fell short, and discharging others who proved to be incorrigibly slow or careless. An accurate time study was made through the use of a stop watch and record blanks, to determine how fast each kind of inspection should be done. This showed that the girls spent a considerable part of their time in partial idleness, talking and half working, or in actually doing nothing.

200. Talking while at work was stopped by seating them far apart. The hours of work were shortened from 10½ per day, first to 9½, and later to 8½; a Saturday half holiday being given them even with the shorter hours. Two recesses of ten minutes each were given them, in the middle of the morning and afternoon, during which they were expected to leave their seats, and were allowed to talk.

201. The shorter hours, and improved conditions, made it possible for the girls to really work steadily, instead of pretending to do so. Piece work was then introduced, a differential rate being paid, not for an increase in output, but for greater accuracy in the inspection; the lots inspected by the over-inspectors forming the basis for the payment of the differential. The work of each girl was measured every hour, and they were all informed whether they were keeping up with their tasks, or how far they had fallen short; and an assistant was sent by the foreman to encourage those who were falling behind, and help them to catch up.

202. The principle of measuring the performance of each workman against a standard at frequent intervals, of keeping them informed as to their progress, and of sending an assistant to help those who were falling down, was carried out throughout the works, and proved to be most useful.

203. The final results of the improved system in the inspecting department are as follows:

1. Thirty-five girls did the work formerly done by one hundred and twenty.

2. The girls averaged from **$6.50 to $9.00 per week instead of $3.50 to $4.50**, as formerly.

3. They worked only 8½ hours per day, with Saturday half-holiday, when they had formerly worked 10½ hours per day.

4. An accurate comparison of the balls which were inspected under the old system of day work with those done under piece work, with over-inspection, showed that, in spite of the large increase in output per girl, there were 58 per cent. more defective balls left in the product as sold under day work than under piece work. In other words, the accuracy of inspection under piece work was one-third greater than that under day work.

204. That thirty-five girls were able to do the work which formerly required about one hundred and twenty is due, not only to the improvement in the work of each girl, owing to better methods, but to the weeding out of the lazy and unpromising candidates, and the substitution of more ambitious individuals.

205. A more interesting illustration of the effect of the improved conditions and treatment is shown in the following comparison: Records were kept of the work of ten girls, all "old hands," and good inspectors, and the improvement made by these skilled hands is undoubtedly entirely due to better management. All of these girls throughout the period of comparison were engaged on the same kind of work, viz.: inspecting bicycle balls, three-sixteenths of an inch in diameter.

206. The work of organization began in March, and although the records for the first three months were not entirely clear, the increased output due to better day work amounted undoubtedly to 33 per cent.

The increase per day from June on day work, to July on piece work, the hours each month being 10½ .... 37 per cent.

207. This increase was due to the introduction of piece work.

Increase per day from July to Aug. Length of working day in July being 10½ hours, and in Aug. 9½ hours, both months piece work... 33 per cent.

Increase Aug. to Sept. Length of working day in Aug. being 9½ hours, and in Sept., 8½ hours.................................... 0.08 per cent.

208. That is, the girls did practically the same amount of work per day in September, in 8½ hours, that they did in August in 9½ hours.

209. To summarize: The same ten girls did on an average each day in September, on piece work, when only working 8½ hours per

day, 2.42 times as much, or nearly two and one-half times as much, in a day (not per hour, the increase per hour was of course much greater) as they had done when working on day work in March with a working day of 10½ hours. They earned $6.50 to $9.00 per week on piece work, while they had only earned $3.50 to $4.50 on day work. The accuracy of inspection under piece work was one-third greater than under day work.

210. The time study for this work was done by my friend, Sanford E. Thompson, C. E., who also had the actual management of the girls throughout the period of transition. At this time, Mr. H. L. Gantt was general superintendent of the company, and the work of systematizing was under the general direction of the writer.

211. It is, of course, evident that the nature of the organizations required to manage different types of business must vary to an enormous extent, from the simple tonnage works (with its uniform product, which is best managed by a single strong man who carries all of the details in his head and who, with a few comparatively cheap assistants, pushes the enterprise through to success), to the large machine works doing a miscellaneous business, with its intricate organization, in which the work of any one man necessarily counts for but little.

212. It is this great difference in the type of the organization required that so frequently renders managers who have been eminently successful in one line utter failures when they undertake the direction of works of a different kind. This is particularly true of men successful in tonnage work who are placed in charge of shops involving much greater detail.

213. In selecting an organization for illustration, it would seem best to choose one of the most elaborate. The manner in which this can be simplified to suit a less intricate case will readily suggest itself to any one interested in the subject. One of the most difficult works to organize is that of a large engineering establishment building miscellaneous machinery, and the writer has therefore chosen this for description.

214. Practically all of the shops of this class are organized upon what may be called the military plan. The orders from the general are transmitted through the colonels, majors, captains, lieutenants and non-commissioned officers to the men. In the same way the orders in industrial establishments go from the manager through superintendents, foremen of shops, assistant

foremen and gang bosses to the men. In an establishment of this kind the duties of the foremen, gang bosses, etc., are so varied, and call for an amount of special information coupled with such a variety of natural ability, that only men of unusual qualities to start with, and who have had years of special training, can perform them in a satisfactory manner. It is because of the difficulty (almost the impossibility) of getting suitable foremen and gang bosses, etc., more than for any other reason, that we so seldom hear of a miscellaneous machine works starting in on a large scale and meeting with much, if any, success for the first few years. This difficulty is not fully realized by the managers of the old well established companies, since their superintendents and assistants have grown up with the business, and have been gradually worked into and fitted for their especial duties through years of training and the process of natural selection. Even in these establishments, however, this difficulty has impressed itself upon the managers so forcibly that most of them have of late years spent thousands of dollars in re-grouping their machine tools for the purpose of making their foremanship more effective. The planers have been placed in one group, slotters in another, lathes in another, etc., so as to demand a smaller range of experience and less diversity of knowledge from their respective foremen. For an establishment, then, of this kind, starting up on a large scale, it may be said to be an impossibility to get suitable superintendents and foremen. The writer found this difficulty at first to be an almost insurmountable obstacle to his work in organizing manufacturing establishments; and after years of experience, overcoming the opposition of the heads of departments and the foremen and gang bosses, and training them to their new duties, still remains the greatest problem in organization. The writer has had comparatively little trouble in inducing workmen to change their ways and to increase their speed, providing the proper object lessons are presented to them, and time enough is allowed for these to produce their effect. It is rarely the case, however, that superintendents and foremen can find any reasons for changing their methods, which, as far as they can see, have been successful. And having, as a rule, obtained their positions owing to their unusual force of character, and being accustomed daily to rule other men, their opposition is generally effective.

215. In the writer's experience, almost all shops are under-

officered. Invariably the number of leading men employed is not sufficient to do the work economically.

216. Under the military type of organization, the foreman is held responsible for the successful running of the entire shop, and when we measure his duties by the standard of the four leading principles of management above referred to, it becomes apparent that in his case these conditions are as far as possible from being fulfilled. His duties may be briefly enumerated as follows: He must lay out the work for the whole shop, see that each piece of work goes in the proper order to the right machine, and that the man at the machine knows just what is to be done and how he is to do it. He must see that the work is not slighted, and that it is done fast, and all the while he must look ahead a month or so, either to provide more men to do the work or more work for the men to do. He must constantly discipline the men and readjust their wages, beside fixing piece work prices and supervising the timekeeping.

217. The first of the four leading principles in management calls for a "clearly defined and circumscribed task." Evidently the foreman's duties are in no way clearly circumscribed. It is left each day entirely to his judgment what small part of the mass of duties before him it is most important for him to attend to, and he staggers along under this fraction of the work for which he is responsible, leaving the balance to be done in many cases as the gang bosses and workmen see fit.

218. The second principle calls for "such conditions that the daily task can always be accomplished." The conditions in his case are always such that it is impossible for him to do it all, and he never even makes a pretence of fulfilling his entire task.

219. The third and fourth principles call for high pay in case the task is successfully done, and low pay in case of failure.

220. The failure to realize the first two conditions, however, renders the application of the last two out of the question. The foreman usually endeavors to lighten his burdens by delegating his duties to the various assistant foremen or gang bosses in charge of lathes, planers, milling machines, vise work, etc. Each of these men is then called upon to perform duties of almost as great variety as those of the foreman himself. The difficulty in obtaining in one man the variety of special information and the different mental and moral qualities necessary to perform all of the duties demanded of these men has been clearly summarized as follows:

221. These nine qualities go to make up a well rounded man:
Brains,
Education,
Special or technical knowledge; manual dexterity or strength.
Tact,
Energy,
Grit,
Honesty,
Judgment or common sense and
Good health.

222. Plenty of men who possess only three of the above qualities can be hired at any time for laborers' wages. Add four of these qualities together and you get a higher priced man. The man combining five of these qualities begins to be hard to find, and those with six, seven, and eight are almost impossible to get. Having this fact in mind, let us go over the duties which a gang boss in charge, say, of lathes or planers, is called upon to perform, and note the knowledge and qualities which they call for:

223. First. He must be a good machinist—and this alone calls for years of special training, and limits the choice to a comparatively small class of men.

224. Second. He must be able to read drawings readily, and have sufficient imagination to see the work in its finished state clearly before him. This calls for at least a certain amount of brains and education.

225. Third. He must plan ahead and see that the right jigs, clamps and appliances, as well as proper cutting tools, are on hand, and are used to set the work correctly in the machine and cut the metal at the right speed and feed. This calls for the ability to concentrate the mind upon a multitude of small details, and take pains with little, uninteresting things.

226. Fourth. He must see that each man keeps his machine clean and in good order. This calls for the example of a man who is naturally neat and orderly himself.

227. Fifth. He must see that each man tnrns out work of the proper quality. This calls for the conservative judgment and the honesty which are the qualities of a good inspector.

228. Sixth. He must see that the men under him work steadily and fast. To accomplish this he should himself be a hustler, a man of energy, ready to pitch in and infuse life into his men by working faster than they do, and this quality is rarely combined with

the painstaking care, the neatness and the conservative judgment demanded as the third, fourth, and fifth requirements of a gang boss.

229. Seventh. He must constantly look ahead over the whole field of work and see that the parts go to the machines in their proper sequence, and that the right job gets to each machine.

230. Eighth. He must, at least in a general way, supervise the timekeeping and fix piece work rates.

Both the seventh and eighth duties call for a certain amount of clerical work and ability, and this class of work is almost always repugnant to the man suited to active executive work, and difficult for him to do; and the rate-fixing alone requires the whole time and careful study of a man especially suited to its minute detail.

231. Ninth. He must discipline the men under him, and readjust their wages; and these duties call for judgment, tact and judicial fairness.

232. It is evident, then, that the duties which the ordinary gang boss is called upon to perform would demand of him a large proportion of the nine attributes mentioned above; and if such a man could be found, he should be made manager or superintendent of a works instead of gang boss. However, bearing in mind the fact that plenty of men can be had who combine four or five of these attributes, it becomes evident that the work of management should be so subdivided that the various positions can be filled by men of this calibre, and a great part of the art of management undoubtedly lies in planning the work in this way. This can, in the judgment of the writer, be best accomplished by ABANDONING THE MILITARY TYPE OF ORGANIZATION and introducing two broad and sweeping changes in the art of management:

233. First. As far as possible the workmen, as well as the gang bosses and foremen, should be entirely relieved of the work of planning, and of all work which is more or less clerical in its nature. All possible brain work should be removed from the shop and centred in the planning or laying-out department, leaving for the foremen and gang bosses work strictly executive in its nature; their duties being to see that the operations planned and directed from the planning room are promptly carried out in the shop. Their time should be spent with the men, teaching them to think ahead, and leading and instructing them in their work.

Second. Throughout the whole field of management the military type of organization should be abandoned, and what may be called the "functional type" substituted in its place.

234. "Functional management" consists in so dividing the work of management that each man from the assistant superintendent down shall have as few functions as possible to perform. If practicable the work of each man in the management should be confined to the performance of a single leading function. Under the ordinary or military type the workmen are divided into groups. The men in each group receive their orders from one man only, the foreman or gang boss of that group. This man is the single agent through which the various functions of the management are brought into contact with the men. Certainly the most marked outward characteristic of "Functional Management" lies in the fact that each workman, instead of coming in direct contact with the management at one point only, namely, through his gang boss, receives his daily orders and help directly from eight different bosses, each of whom performs his own particular function. Four of these bosses are in the planning room and of these three send their orders to and receive their returns from the men, usually in writing. Four others are in the shop and personally help the men in their work, each boss helping in his own particular line or function only. Some of these bosses come in contact with each man only once or twice a day and then for a few minutes perhaps, while others are with the men all the time, and help each man frequently. The functions of one or two of these bosses require them to come in contact with each workman for so short a time each day that they can perform their particular duties perhaps for all of the men in the shop; and in their line they manage the entire shop, while other bosses are called upon to help their men so much and so often that each boss can perform his function for but a few men, and in this particular line a number of bosses are required, all performing the same function but each having his particular group of men to help. Thus the grouping of the men in the shop is entirely changed, each workman belonging to eight different groups according to the particular functional boss whom he happens to be working under at the time.

235. The following is a brief description of the duties of the four types of executive functional bosses which the writer has found it profitable to use in the active work of the shop: "Gang Bosses," "Speed Bosses," "Inspector," and "Repair Bosses."

236. The GANG BOSS has charge of the preparation of all work up to the time that the piece is set in the machine. It is his duty to see that every man under him has at all times at least one piece of work at his machine, with all the jigs, templets, drawings, driving mechanism, sling chains, etc., ready to go into his machine as soon as the piece he is actually working on is done. The gang boss must show his men how to set their work in their machines in the quickest time, and see that they do it. He is responsible for the work being accurately and quickly set, and should be not only able but willing to pitch in himself and show the men how to set the work in record time.

237. The SPEED BOSS must see that the proper cutting tools are used for each piece of work, that the work is properly driven, that the cuts are started in the right part of the piece, and that the best speeds and feeds and depth of cut are used. His work begins only after the piece is in the lathe or planer, and ends when the actual machining ends. The speed boss must not only advise his men how to best do this work, but he must see that they do it in the quickest time, and that they use the speeds and feeds and depth of cut as directed on the instruction card. In many cases he is called upon to demonstrate that the work can be done in the specified time by doing it himself in the presence of his men.

238. The INSPECTOR is responsible for the quality of the work, and both the workmen and speed bosses must see that the work is all finished to suit him. This man can, of course, do his work best if he is a master of the art of finishing work both well and quickly.

239. The REPAIR BOSS sees that each workman keeps his machine clean, free from rust and scratches, and that he oils and treats it properly, and that all of the standards established for the care and maintenance of the machines and their accessories are rigidly maintained, such as care of belts and shifters, cleanliness of floor around machines, and orderly piling and disposition of work.

240. The following is an outline of the duties of the four functional bosses who are a part of the planning department, and who in their various functions represent this department in its connection with the men. The first three of these send their directions to and receive their returns from the men, mainly in writing. These four representatives of the planning room are, the "order

of work clerk," "instruction card men," "time and cost clerk," and "shop disciplinarian."

241. "*Order of Work or Route Clerk.*"—After the proper man in the planning department has laid out the exact route which each piece of work is to travel through the shop from machine to machine in order that it may be finished at the time it is needed for assembling, and the work done in the most economical way, the "route clerk" daily writes lists instructing the workmen and also all of the executive shop bosses as to the exact order in which the work is to be done by each class of machines or men, and these lists constitute the chief means for directing the workmen in this particular function.

242. *Instruction Card Men.*—The "instruction card," as its name indicates, is the chief means employed by the planning department in instructing both the executive bosses and the men in all of the details of their work. It tells them briefly the general and detail drawing to refer to, the piece number and the cost order number to charge the work to, the special jigs, fixtures, or tools to use, where to start each cut, the exact depth of each cut, and how many cuts to take, the speed and feed to be used for each cut, and the time within which each operation must be finished. It also informs them as to the piece rate, the differential rate or the premium to be paid for completing the task within the specified time (according to the system employed); and further, when necessary, refers them by name to the man who will give them especial directions. This instruction card is filled in by one or more members of the planning department, according to the nature and complication of the instructions, and bears the same relation to the planning room that the drawing does to the drafting room. The man who sends it into the shop and who, in case difficulties are met with in carrying out the instructions, sees that the proper man sweeps these difficulties away, is called "the instruction card foreman."

243. *Time and Cost Clerk.*—This man sends to the men through the "instruction card" all the information they need for recording their time and the cost of the work, and secures proper returns from them and refers these for entry to the cost and time record clerks in the planning room.

244. *Shop Disciplinarian.*—In case of insubordination or impudence, repeated failure to do their duty, lateness or unexcused absence, the shop disciplinarian takes the workman or bosses in

hand and applies the proper remedy, and sees that a complete record of each man's virtues and defects is kept. This man should also have much to do with readjusting the wages of the workmen. At the very least, he should invariably be consulted before any change is made. One of his important functions should be that of peace-maker.

245. Thus we see, under Functional Foremanship, the work which, with the military type of organization, was done by the single "gang boss," subdivided among eight men.

"*Route Clerks*," "*Instruction Card Men*," "*Cost and Time Clerks*."—Who plan and give directions from the planning room.

"*Gang Bosses*," "*Speed Bosses*," "*Inspectors*," "*Repair Bosses*."—Who show the men how to carry out their instructions, and see that the work is done at the proper speed.

And the "*Shop Disciplinarian*."—Who performs this function for the entire establishment.

246. The greatest good resulting from this change is that it becomes possible in a comparatively short time to train bosses who can really and fully perform the functions demanded of them, while under the old system it took years to train men who were after all able to thoroughly perform only a portion of their duties. A glance at the nine qualities needed for a well rounded man and then at the duties of the "functional foreman" will show that each of these men requires but a limited number of the nine qualities in order to successfully fill his position; and that the special knowledge which he must acquire forms only a small part of that needed by the old style gang boss. The writer has seen men taken (some of them from the ranks of the workmen, others from the old style bosses and others from among the graduates of industrial schools, technical schools and colleges) and trained to become efficient functional foremen in from six to eighteen months. Thus it becomes possible with functional foremanship to thoroughly and completely equip even a new company starting on a large scale with competent officers in a reasonable time, which is entirely out of the question under the old system. Another great advantage resulting from divided foremanship is that it becomes entirely practicable to apply the four leading principles of management to the bosses as well as to the workmen. Each foreman can have a task assigned him which is so accurately measured that he will be kept fully occupied and still will daily

be able to perform his entire function. This renders it possible to pay him high wages when he is successful by giving him a premium similar to that offered the men and leave him with low pay when he fails.

247. The full possibilities of functional foremanship, however, will not have been realized until almost all of the machines in the shop are run by men who are of smaller calibre and attainments, and who are therefore cheaper than those required under the old system. The adoption of standard tools, appliances and methods throughout the shop, the planning done in the planning room and the detailed instructions sent them from this department, added to the direct help received from the four executive bosses, permit the use of comparatively cheap men even on complicated work. Of the men in the machine shop of the Bethlehem Steel Company engaged in running the roughing machines, and who were working under the bonus system when the writer left them, about 95 per cent. were handy men trained up from laborers. And on the finishing machines working on bonus about 25 per cent. were handy men.

248. To fully understand the importance of the work which was being done by these former laborers, it must be borne in mind that a considerable part of their work was very large and expensive. The forgings which they were engaged in roughing and finishing weighed frequently many tons.

249. Of course they were paid more than laborer's wages, though not as much as skilled machinists. The work in this shop was most miscellaneous in its nature.

250. Functional foremanship is already in limited use in many of the best managed shops. A number of managers have seen the practical good that arises from allowing two or three men especially trained in their particular lines to deal directly with the men instead of at second hand through the old style gang boss as a mouthpiece. So deep rooted, however, is the conviction that the very foundation of management rests in the military type as represented by the principle that no workman can work under two bosses at the same time, that all of the managers who are making limited use of the functional plan seem to feel it necessary to apologize for or explain away their use of it; as not really in this particular case being a violation of that principle. The writer has never yet found one, except among the works which he had assisted in organizing, who came out squarely and acknowledged

that he was using functional foremanship because it was the right principle.

251. The writer introduced five of the elements of functional foremanship into the management of the small machine shop of the Midvale Steel Company of Philadelphia while he was foreman of that shop in 1882-1883—the "Instruction Card Man," the "Time Clerk," the "Inspector," the "Gang Boss," and the "Shop Disciplinarian." Each of these functional bosses dealt directly with the workmen instead of giving their orders through the "Gang Boss." The dealings of the "Instruction Card Man" and "Time Clerk" with the workmen were mostly in writing, and the writer himself performed the functions of "Shop Disciplinarian," so that it was not until he introduced the "Inspector," with orders to go straight to the men instead of to the gang boss, that he appreciated the desirability of functional foremanship as a distinct principle in management.

252. The prepossession in favor of the military type was so strong with the managers and owners of Midvale that it was not until years after functional foremanship was in continual use in this shop that he dared to advocate it to his superior officers as the correct principle.

253. Until very recently in his organization of works he has found it best to first introduce five or six of the elements of functional foremanship quietly, and get them running smoothly in a shop before calling attention to the principle involved; and when the time for this announcement comes, it invariably acts as the proverbial red rag on the bull. It is only within the last twleve years that the writer subdivided the duties of the "old gang boss" who spent his whole time with the men into the four functions of "Speed Boss," "Repair Boss," "Inspector," and "Gang Boss," and it is the introduction of these four shop bosses directly helping the men (particularly that of the "Speed Boss") in place of the single old boss, that has produced the greatest improvement in the shop.

254. When functional foremanship is introduced in a large shop, it is desirable that all of the bosses who are performing the same function should have their own foreman over them; for instance, the speed bosses should have a speed foreman over them, the gang bosses, a head gang boss; the inspectors, a chief inspector, etc., etc. The functions of these over foremen are twofold: First, that of teaching each of the bosses under them the exact nature of

his duties, and at the start, also of nerving and bracing them up to the point of insisting that the workmen shall carry out the orders exactly as specified on the instruction cards. This is a difficult task at first, as the workmen have been accustomed for years to do the details of the work to suit themselves, and many of them are intimate friends of the bosses and believe they know quite as much about their business as the latter. The second function of the over-foreman is to smooth out the difficulties which arise between the different types of bosses who in turn directly help the men. The "Speed Boss," for instance, always follows after the "gang boss" on any particular job in taking charge of the workman. In this way their respective duties come in contact edgeways, as it were, for a short time, and at the start there is sure to be more or less friction between the two. If two of these bosses meet with a difficulty which they cannot settle, they send for their respective over-foremen, who are usually able to straighten it out. In case the latter are unable to agree on the remedy, the case is referred by them to the assistant superintendent, whose duties, for a certain time at least, may consist largely in arbitrating such difficulties and thus establishing the unwritten code of laws by which the shop is governed. This serves as one example of what is called the "exception principle" in management, which is referred to later.

255. Before leaving this portion of the subject the writer wishes to call attention to the analogy which functional foremanship bears to the management of a large, up-to-date school. In such a school the children are each day successively taken in hand by one teacher after another who is trained in his particular specialty, and they are in many cases disciplined by a man particularly trained in this function. The old style, one teacher to a class plan is entirely out of date.

256. The writer has found that better results are attained by placing the planning department in one office situated, of course, as close to the centre of the shop or shops as practicable, rather than by locating its members in different places according to their duties. This department performs more or less the functions of a clearing house. In doing their various duties, its members must exchange information frequently, and since they send their orders to and receive their returns from the men in the shop, principally in writing, simplicity calls for the use, when possible, of a single piece of paper for each job for conveying the instructions of the

different members of the planning room to the men and another similar paper for receiving the returns from the men to the department. Writing out these orders and acting promptly on receipt of the returns and recording same requires the members of the department to be close together. The large machine shop of the Bethlehem Steel Company was more than a quarter of a mile long, and this was successfully run from a single planning room situated close to it. The manager, superintendent, and their assistants should, of course, have their offices adjacent to the planning room and, if practicable, the drafting room should be near at hand, thus bringing all of the planning and purely brain work of the establishment close together. The advantages of this concentration were found to be so great at Bethlehem that the general offices of the company, which were formerly located in the business part of the town about a mile and a half away, were moved into the middle of the works adjacent to the planning room.

257. The shop (indeed the whole works) should be managed, not by the manager, superintendent, or foreman, but by the planning department. The daily routine of running the entire works should be carried on by the various functional elements of this department, so that, in theory at least, the works could run smoothly even if the manager, superintendent and their assistants outside the planning room were all to be away for a month at a time.

258. The following are the leading functions of the Planning Department:

A.—The complete analysis of all orders for machines or work taken by the company.

B.—Time study for all work done by hand throughout the works, including that done in setting the work in machines, and all bench, vise work and transportation, etc.

C.—Time study for all operations done by the various machines.

D.—The balance of all materials, raw materials, stores and finished parts, and the balance of the work ahead for each class of machines and workmen.

E.—The analysis of all inquiries for new work received in the sales department and promises for time of delivery.

F.—The cost of all items manufactured with complete expense analysis and complete monthly comparative cost and expense exhibits.

G.—The pay department.

H.—The Mnemonic Symbol System for identification of parts and for charges.

I.—Information bureau.

J.—Standards.

K.—Maintenance of system and plant, and use of the tickler.

L.—Messenger system and post office delivery.

M.—Employment bureau.

N.—The shop disciplinarian.

O.—A mutual accident insurance association.

P.—Rush order department.

Q.—Improvement of system or plant.

259. A.—*The Complete Analysis of All Orders for Machines or Work Taken by the Company.*

This analysis should indicate the designing and drafting required, the machines or parts to be purchased and all data needed by the purchasing agent, and as soon as the necessary drawings and information come from the drafting room the lists of patterns, castings and forgings to be made, together with all instructions for making them, including general and detail drawing, piece number, the Mnemonic Symbol belonging to each piece (as referred to in "H")—a complete analysis of the successive operations to be done on each piece, and the exact route which each piece is to travel from place to place in the works.

260. B.—*Time Study for All Work Done by Hand Throughout the Works, Including That Done in Setting the Work in Machines, and All Bench, Vise Work, and Transportation, etc.*

This information for each particular operation should be obtained by summing up the various "unit times" of which it consists. To do this, of course, requires the men performing this function to keep continually posted as to the best methods and appliances to use, and also to frequently consult with and receive advice from the executive gang bosses who carry out this work in the shop, and from the man in the department of standards and maintenance of plant (J) beneath. The actual study of "unit times," of course, forms the greater part of the work of this section of the planning room.

261. C.—*Time Study for All Operations Done by the Various Machines.*

This information is best obtained from slide rules, one of which is made for each machine tool or class of machine tools throughout the works; one, for instance, for small lathes of the same type, one for planers of same type, etc. These slide rules show the best way to machine each piece and enable detailed directions to be given the workman as to how many cuts to take, where to start each cut, both for roughing out work and finishing it, the depth of the cut, the best feed and speed, and the exact time required to do each operation.

262. The information obtained through function "B," together with that obtained through "C," afford the basis for fixing the proper piece rate, differential rate or the premium to be paid (according to the system employed).

263. D.—*The Balance of All Materials, Raw Materials, Stores and Finished Parts, and the Number of Days' Work Ahead for Each Class of Machines and Workmen.*

Returns showing all receipts, as well as the issue of all raw materials, stores, partly finished work and completed parts and machines, repair parts, etc., daily pass through the balance clerk, and each item of which there have been issues or receipts, or which has been appropriated to the use of a machine about to be manufactured, is daily balanced. Thus the balance clerk can see that the required stocks of materials are kept on hand by notifying at once the purchasing agent or other proper party when the amount on hand falls below the prescribed figure. The balance clerk should also keep a complete running balance of the hours of work ahead for each class of machines and workmen, receiving for this purpose daily from A, B and C statements of the hours of new work entered, and from the inspectors and daily time cards a statement of the work as it is finished. He should keep the manager and sales department posted through daily or weekly condensed reports as to the number of days of work ahead for each department, and thus enable them to obviate either a congestion or scarcity of work.

264. E.—*The Analysis of All Inquiries for New Work Received in the Sales Department and Promises for Time of Delivery.*

The man or men in the planning room who performs the duties indicated at " A " above should consult with B and C and obtain from them approximately the time required to do the work inquired for, and from D the days of work ahead for the various machines and departments, and inform the sales department as to the probable time required to do the work and the earliest date of delivery.

265. F.—*The Cost of All Items Manufactured With Complete Expense Analysis and Complete Monthly Comparative Cost and Expense Exhibits.*

The books of the company should be monthly closed and balanced as completely as they usually are at the end of the year, and the exact cost of each article of merchandise finished during the previous month should be entered on a comparative cost sheet. The expense exhibit should also be a comparative sheet. The cost account should be a completely balanced account, not a memorandum account as it generally is; and the entire expenses of the establishment, direct and indirect, including the administration and sales expense, should be charged to the cost of the product which is to be sold.

266. G.—*The Pay Department.*

The pay department should include not only a record of the time and wages and piece work earnings of each man, and his weekly or monthly payment, but the entire supervision of the arrival and departure of the men from the works and the various checks needed to insure against error or cheating. It is desirable that some one of the " exception systems " of time keeping should be used.

267. H.—*The Mnemonic Symbol System for Identification of Parts and for Charges.*

Some one of the Mnemonic Symbol Systems should be used instead of numbering the parts or orders for identifying the various articles of manufacture, as well as the operations to be performed on each piece and the various expense charges of the establishment. This becomes a matter of great importance when written directions are sent from the planning room to the men, and the men make their returns in writing. The clerical work and chances for error are thereby greatly diminished.

268. I.—*Information Bureau.*

The information bureau should include catalogues of drawings (providing the drafting room is close enough to the planning room) as well as all records and reports for the whole establishment. The art of properly indexing information is by no means a simple one, and as far as possible it should be centred in one man.

269. J.—*Standards.*

The adoption and maintenance of standard tools, fixtures and appliances down to the smallest item throughout the works and office, as well as the adoption of standard methods of doing all operations which are repeated, is a matter of importance, so that under similar conditions the same appliances and methods shall be used throughout the plant. This is an absolutely necessary preliminary to success in assigning daily tasks which are fair and which can be carried out with certainty.

270. K.—*Maintenance of System and Plant, and Use of the Tickler.*

One of the most important functions of the planning room is that of the maintenance of the entire system, and of standard methods and appliances throughout the establishment, including the planning room itself. An elaborate time table should be made out showing daily the time when and place where each report is due, which is necessary to carry on the work and to maintain the system. It should be the duty of the member of the planning room in charge of this function to find out at each time through the day when reports are due, whether they have been received, and if not, to keep bothering the man who is behind hand until he has done his duty. Almost all of the reports, etc., going in and out of the planning room can be made to pass through this man. As a mechanical aid to him in performing his function the tickler is invaluable. The best type of tickler is one which has a portfolio for each day in the year large enough to insert all reminders and even quite large instruction cards and reports without folding. In maintaining methods and appliances, notices should be placed in the tickler in advance, to come out at proper intervals throughout the year for the inspection of each element of the system and the inspection and overhauling of all standards as well as the examination and repairs at stated intervals of parts of machines, boilers, engines, belts, etc., likely to wear out or give trouble, thus preventing breakdowns and delays. One tickler can be used for the entire works and is preferable to a number of individual ticklers; each man can remind himself of his various small routine duties to be performed either daily or weekly, etc., and which might be otherwise overlooked by sending small reminders, written on slips of paper, to be placed in the tickler and returned to him at the proper time. Both the tickler and a thoroughly systematized messenger service should be immediately adjacent to this man in the planning room, if not directly under his management.

271. The proper execution of this function of the planning room will relieve the superintendent of some of the most vexatious and time-consuming of his duties and at the same time the work will be done more thoroughly and cheaper than if he does it himself. By the adoption of standards and the use of instruction cards for overhauling machinery, etc., and the use of a tickler as above described, the writer reduced the repair force of the Midvale Steel Works to one-third its size while he was in the position of master mechanic. (There was no planning department, however, in the works at that time.)

272. L.—*Messenger System and Post Office Delivery.*

The messenger system should be thoroughly organized and records kept showing which of the boys are the most efficient. This should afford one of the best opportunities for selecting boys fit to be taught trades, as apprentices or otherwise.

273. There should be a regular half hourly post office delivery system for collecting and distributing routine reports and records and messages in no especial hurry throughout the works.

274. M.—*Employment Bureau.*

The selection of the men who are employed to fill vacancies or new positions should receive the most careful thought and attention and should be under the supervision of a competent man who will inquire into the experience and especial fitness and character of applicants and keep constantly revised lists of men suitable for the various positions in the shop. In this section of the planning room an individual record of each of the men in the works can well be kept showing his punctuality, absence without excuse, violation of shop rules, spoiled work or damage to machines or tools, as well as his skill at various kinds of work; average earnings, and other good qualities, for the use of this department as well as the shop disciplinarian.

275. N.—*The Shop Disciplinarian.*

This man may well be closely associated with the employment bureau and, if the works is not too large, the two functions can be performed by the same man. The knowledge of character and of the qualities needed for various positions acquired in disciplining the men should be useful in selecting them for employment. This man should, of course, consult constantly with the various foremen and bosses, both in his function as disciplinarian and in the employment of men.

276. O.—*A Mutual Accident Insurance Association.*

A Mutual Accident Insurance Association should be established, to which the company contributes as well as the men. The object of this Association is twofold: First, the relief of men who are injured, and second, an opportunity of returning to the workmen all fines which are imposed upon them in disciplining them, and for damage to company's property or work spoiled.

277. *P.—Rush Order Department.*

Hurrying through parts which have been spoiled or have developed defects, and also special repair orders for customers, should receive the attention of one man.

278. Q.—*Improvement of System or Plant.*

One man should be especially charged with the work of improvement in the system and in the running of the plant.

279. This type of organization has such an appearance of complication and there are so many new positions outlined in the planning room which do not exist even in a well managed establishment of the old school, that it seems desirable to again call attention to the fact that, with the exception of the study of unit times and one or two minor functions, each item of work which is performed in the planning room with the superficial appearance of great complication must also be performed by the workmen in the shop under the old type of management, with its single cheap foreman and the appearance of great simplicity. In the first case, however, the work is done by an especially trained body of men who work together like a smoothly running machine, and in the second by a much larger number of men very poorly trained and ill-fitted for this work, and each of whom while doing it is taken away from some other job for which he is well trained. The work which is now done by one sewing machine, intricate in its appearance, was formerly done by a number of women with no apparatus beyond a simple needle and thread.

280. There is no question that the cost of production is lowered by separating the work of planning and the brain work as much as possible from the manual labor. When this is done, however, it is evident that the brain workers must be given sufficient work to keep them fully busy all the time. They must not be allowed to stand around for a considerable part of their time waiting for their particular kind of work to come along, as is so frequently the case.

281. The belief is almost universal among manufacturers that for economy the number of brain workers (or non-producers, as they are called) should be as small as possible in proportion to the number of producers (*i.e.*—those who actually work with their hands). An examination of the most successful establishments will, however, show that the reverse is true. A number of years ago the writer made a careful study of the proportion of producers to non-producers in three of the largest and most successful companies in the world, who were engaged in doing the same work in a general way. One of these companies was in France,

one in Germany, and one in the United States. Being to a certain extent rivals in business and situated in different countries, naturally neither one had anything to do with the management of the other; and in the course of his investigation, the writer found that the managers had never even taken the trouble to ascertain the exact proportion of non-producers to producers in their respective works; so that the organization of each company was an entirely independent evolution.

282. By "non-producers," the writer means such employees as all of the general officers, the clerks, foremen, gang bosses, watchmen, messenger boys, draftsmen, salesmen, etc.; and by "producers," only those who actually work with their hands.

In the French and German works there was found to be in each case one non-producer to between six and seven producers, and in the American works one non-producer to about seven producers. The writer found that in the case of another works, doing the same kind of business and whose management was notoriously bad, the proportion of non-producers to producers was one non-producer to about eleven producers. These companies all had large forges, foundries, rolling mills and machine shops turning out a miscellaneous product, much of which was machined. They turned out a highly wrought, elaborate and exact finished product, and did an extensive engineering and miscellaneous machine construction business.

283. In the case of a company doing a manufacturing business with a uniform and simple product for the maximum economy, the number of producers to each non-producer would of course be larger. No manager need feel alarmed then when he sees the number of non-producers increasing in proportion to producers, providing the non-producers are busy all of their time, and providing, of course, that in each case they are doing efficient work.

284. It would seem almost unnecessary to dwell upon the desirability of standardizing, not only all of the tools, appliances and implements throughout the works and office, but also the methods to be used in the multitude of small operations which are repeated day after day. There are many good managers of the old school, however, who feel that this standardization is not only unnecessary but that it is undesirable, their principal reason being that it is better to allow each workman to develop his individuality by choosing the particular implements and methods which suit him best. And there is considerable weight in this contention

when the scheme of management is to allow each workman to do the work as he pleases and hold him responsible for results. Unfortunately, in ninety-nine out of a hundred such cases only the first part of this plan is carried out. The workman chooses his own methods and implements, but is NOT HELD IN ANY STRICT SENSE ACCOUNTABLE unless the quality of the work is so poor or the quantity turned out is so small as to almost amount to a scandal. In the type of management advocated by the writer, this complete standardization of all details and methods is not only desirable but absolutely indispensable as a preliminary to specifying the time in which each operation shall be done, and then insisting that it shall be done within the time allowed.

285. Neglecting to take the time and trouble to thoroughly standardize all of such methods and details is one of the chief causes for setbacks and failure in introducing this system. Much better results can be attained, even if poor standards be adopted, than can be reached if some of a given class of implements are the best of their kind while others are poor. It is uniformity that is required. Better have them uniformly second class than mainly first with some second and some third class thrown in at random. In the latter case the workmen will almost always adopt the pace which conforms to the third class instead of the first or second. In fact, however, it is not a matter involving any great expense or time to select in each case standard implements which shall be nearly the best or the best of their kinds. The writer has never failed to make enormous gains in the economy of running by the adoption of standards.

286. It was in the course of making a series of experiments with various air hardening tool steels with a view to adopting a standard for the Bethlehem works that Mr. White, together with the writer, discovered the Taylor-White process of treating tool steel, which marks a distinct improvement in the art; and the fact that this improvement was made not by manufacturers of tool steel but in the course of the adoption of standards, shows both the necessity and fruitfulness of methodical and careful investigation in the choice of much neglected details. The economy to be gained through the adoption of uniform standards is hardly realized at all by the managers of this country. No better illustration of this fact is needed than that of the present condition of the cutting tools used throughout the machine shops of the United States. Hardly a shop can be found in which tools

made from a dozen different qualities of steel are not used side by side, in many cases with little or no means of telling one make from another; and in addition, the shape of the cutting edge of the tool is in most cases left to the fancy of each individual workman. When one realizes that the cutting speed of the best treated air hardening steel is for a given depth of cut, feed and quality of metal being cut, say sixty feet per minute, while with the same shaped tool made from the best carbon tool steel and with the same conditions, the cutting speed will be only twelve feet per minute, it becomes apparent how little the necessity for rigid standards is appreciated.

287. As another illustration: The machines of the country are still driven by belting. The motor drive, while it is coming, is still in the future. There is not one establishment in one hundred that does not leave the care and tightening of the belts to the judgment of the individual who runs the machine, although it is well known to all who have given any study to the subject that the most skilled machinist cannot properly tighten a belt without the use of belt clamps fitted with spring balances to properly register the tension. And the writer showed in a paper presented to this Society in 1893, giving the results of an experiment tried on all of the belts in a machine shop and extending through nine years, in which every detail of the care and tightening and tension of each belt was recorded, that belts properly cared for according to a standard method by a trained laborer would average twice the pulling power and only a fraction of the interruptions to manufacture of those tightened according to the usual methods. The loss now going on throughout the country from failure to adopt and maintain standards for all small details is simply enormous.

It is, however, a good sign for the future that a firm such as Messrs. Dodge & Day of Philadelphia, who are making a specialty of standardizing machine shop details, find their time fully occupied.

288. What may be called the "Exception Principle" in management is coming more and more into use; although like many of the other elements of this art, it is used in isolated cases, and in most instances without recognizing it as a principle which should extend throughout the entire field. It is not an uncommon sight, though a sad one, to see the manager of a large business fairly swamped at his desk with an ocean of letters and reports, on each

of which he thinks that he should put his initial or stamp. He feels that by having this mass of detail pass over his desk he is keeping in close touch with the entire business. The exception principle is directly the reverse of this. Under it the manager should receive only condensed, summarized, and invariably comparative reports, covering, however, all of the elements entering into the management, and even these summaries should all be carefully gone over by an assistant before they reach the manager, and have all of the exceptions to the past averages or to the standards pointed out, both the especially good and especially bad exceptions, thus giving him in a few minutes a full view of progress which is being made, or the reverse, and leaving him free to consider the broader lines of policy and to study the character and fitness of the important men under him. The exception principle can be applied in many ways, and the writer will endeavor to give some further illustrations of it later.

289. The writer has dwelt at length upon the desirability of concentrating as much as possible clerical and brain work in the planning department. There is, however, one such important exception to this rule that it would seem desirable to call attention to it. As already stated, the planning room gives its orders and instructions to the men mainly in writing, and of necessity must also receive prompt and reliable written returns and reports which shall enable its members to issue orders for the next movement of each piece, lay out the work for each man for the following day, properly post the balance of work and materials accounts, enter the records on cost accounts and also enter the time and pay of each man on the pay sheet. There is no question that all of this information can be given both better and cheaper by the workman direct than through the intermediary of a walking time keeper, providing the proper instruction and report system has been introduced in the works with carefully ruled and printed instruction and return cards, and particularly providing a complete Mnemonic system of symbols has been adopted so as to save the workmen the necessity of doing much writing. The principle to which the writer wishes to call particular attention is that the only way in which workmen can be induced to write out all of this information accurately and promptly is by having each man write his own time while on day work and pay when on piece work on the same card on which he is to enter the other desired information, and then refusing to enter his pay on the pay sheet

until after all of the required information has been correctly given by him. Under this system as soon as a workman completes a job and at quitting time, whether the job is completed or not, he writes on a printed time card all of the information needed by the planning room in connection with that job, signs it and forwards it at once to the planning room. On arriving in the planning room each time card passes through the order of work or route clerk, the balance clerk, the cost clerk, etc., on its way to the pay sheet, and unless the workman has written the desired information the card is sent back to him, and he is apt to correct and return it promptly so as to have his pay entered up. The principle is clear that if one wishes to have routine clerical work done promptly and correctly it should somehow be attached to the pay card of the man who is to give it. This principle, of course, applies to the information desired from inspectors, gang bosses and others as well as workmen, and to reports required from various clerks. In the case of reports, a pay coupon can be attached to the report which will be detached and sent to the pay sheet as soon as the report has been found correct.

290. Before starting to make any radical changes leading toward an improvement in the system of management, it is desirable, and for ultimate success in most cases necessary, that the directors and the important owners of an enterprise shall be made to understand, at least in a general way, what is involved in the change. They should be informed of the leading objects which the new system aims at, such, for instance, as rendering mutual the interests of employer and employee through "high wages and a low labor cost," the gradual selection and development of a body of first class picked workmen who will work extra hard and receive extra high wages and be dealt with individually instead of in masses; and that this can only be accomplished through the adoption of precise and exact methods, and having each smallest detail, both as to methods and appliances, carefully selected so as to be the best of its kind. They should understand the general philosophy of the system and should see that, as a whole, it must be in harmony with its few leading ideas, and that principles and details which are admirable in one type of management have no place whatever in another. They should be shown that it pays to employ an especial corps to introduce a new system just as it pays to employ especial designers and workmen to build a new plant; that, while a new system is being intro-

duced, almost twice the number of foremen are required as are needed to run it after it is in; that all of this costs money, but that, unlike a new plant, returns begin to come in almost from the start from improved methods and appliances as they are introduced, and that in most cases the new system more than pays for itself as it goes along; that time, and a great deal of time, is involved in a radical change in management, and that in the case of a large works if they are incapable of looking ahead and patiently waiting for from two to four years, they had better leave things just as they are, since a change of system involves a change in the ideas, point of view and habits of many men with strong convictions and prejudices, and that this can only be brought about slowly and chiefly through a series of object lessons, each of which takes time, and through continued reasoning; and that for this reason, after deciding to adopt a given type, the necessary steps should be taken as fast as possible, one after another, for its introduction. They should be convinced that an increase in the proportion of non-producers to producers means increased economy and not red tape, providing the non-producers are kept busy at their respective functions. They should be prepared to lose some of their valuable men who cannot stand the change and also for the continued indignant protest of many of their old and trusted employees who can see nothing but extravagance in the new ways and ruin ahead. It is a matter of the first importance that, in addition to the directors of the company, all of those connected with the management should be given a broad and comprehensive view of the general objects to be attained and the means which will be employed. They should fully realize before starting on their work and should never lose sight of the fact that the great object of the new organization is to bring about two momentous changes in the men:

291. First. A complete revolution in their mental attitude toward their employers and their work; and

Second. As a result of this change of feeling such an increase in their determination and physical activity, and such an improvement in the conditions under which the work is done as will result in many cases in their turning out from two to three times as much work as they have done in the past.

292. First, then, they must be brought to see that the new system changes their employers from antagonists to friends who are working as hard as possible side by side with them, all pushing

in the same direction and all helping to bring about such an increase in the output and to so cheapen the cost of production that the men will be paid permanently from thirty to one hundred per cent. more than they have earned in the past, and that there will still be a good profit left over for the company. At first workmen cannot see why, if they do twice as much work as they have done, they should not receive twice the wages. When the matter is properly explained to them and they have time to think it over, they will see that in most cases the increase in output is quite as much due to the improved appliances and methods, to the maintenance of standards and to the great help which they receive from the men over them as to their own harder work; and they will realize that the company must pay for the introduction of the improved system, which costs sometimes thousands of dollars, and also the salaries of the additional foremen and of the clerks, etc., in the planning room as well as tool room and other expenses, and that, in addition, the company is entitled to an increased profit quite as much as they are. All but a few of them will come to understand in a general way that under the new order of things they are co-operating with their employers to make as great a saving as possible and that they will receive permanently their fair share of this gain.

293. Second. After the men acquiesce in the new order of things and are willing to do their part toward cheapening production, it will take time for them to change from their old easy-going ways to a higher rate of speed, and to learn to stay steadily at their work, think ahead and make every minute count. A certain percentage of them, with the best of intentions, will fail in this and find that they have no place in the new organization, while still others, and among them some of the best workers who are, however, either stupid or stubborn, can never be made to see that the new system is as good as the old; and these, too, must drop out. Let no one imagine, however, that this great change in the mental attitude of the men and the increase in their activity can be brought about by merely talking to them. Talking will be most useful (in fact indispensable), and no opportunity should be lost of explaining matters to them patiently, one man at a time, and giving them every chance to express their views.

294. Their real instruction, however, must come through a series of object lessons. They must be convinced that a great increase

in speed is possible by seeing here and there a man among them increase his pace and double or treble his output. They must see this pace maintained until they are convinced that it is not a mere spurt; and, most important of all, they must see the men who "get there" in this way receive a proper increase in wages and become satisfied. It is only with these object lessons in plain sight that the new theories can be made to stick. It will be in presenting these object lessons and in smoothing away the difficulties so that the high speed can be maintained, and in assisting to form public opinion in the shop, that the great efficiency of functional foremanship under the direction of the planning room will first become apparent.

295. In reaching the final high rate of speed which shall be steadily maintained, the broad fact should be realized that the men must pass through several distinct phases, rising from one plane of efficiency to another until the final level is reached. First they must be taught to work under an improved system of day work. Each man must learn how to give up his own particular way of doing things, adapt his methods to the many new standards and grow accustomed to receiving and obeying directions covering details large and small which in the past have been left to his individual judgment. At first the workmen can see nothing in all of this but red tape and useless and impertinent interference, and time must be allowed them to recover from their irritation, not only at this but at every stage in their upward march. If they have been classed together and paid uniform wages for each class, the better men should be singled out and given higher wages so that they shall distinctly recognize the fact that each man is to be paid according to his individual worth. After becoming accustomed to direction in minor matters, they must gradually learn to obey instructions as to the pace at which they are to work, and grasp the idea, first, that the planning department knows accurately how long each operation should take; and second, that sooner or later they will have to work at the required speed if they expect to prosper. After they are used to following the speed instructions given them, then one at a time they can be raised to the level of maintaining a rapid pace throughout the day. And it is not until this final step has been taken that the full measure of the value of the new system will be felt by the men through daily receiving larger wages, and by the company through a materially larger output and lower cost of pro-

duction. It is evident, of course, that all of the workmen in the shop will not rise together from one level to another. Those engaged in certain lines of work will have reached their final high speed while others have barely taken the first step. The efforts of the new management should not be spread out thin over the whole shop. They should rather be focussed upon a few points, leaving the ninety and nine under the care of their former shepherds. After the efficiency of the men who are receiving especial assistance and training has been raised to the desired level, the means for holding them there should be perfected, and they should never be allowed to lapse into their old ways. This will, of course, be accomplished in the most permanent way and rendered almost automatic, either through introducing "task work with a bonus" or the "differential rate."

Before taking any steps toward changing methods the manager should realize that at no time during the introduction of the system should any broad, sweeping changes be made which seriously affect a large number of the workmen. It would be preposterous, for instance, in going from day to piece work to start a large number of men on piece work at the same time. Throughout the early stages of organization each change made should affect one workman only, and after the single man affected has become used to the new order of things, then change one man after another from the old system to the new, slowly at first, and rapidly as public opinion in the shop swings around under the influence of proper object lessons. Throughout a considerable part of the time, then, there will be two distinct systems of management in operation in the same shop; and in many cases it is desirable to have the men working under the new system managed by an entirely different set of foremen, etc., from those under the old.

296. The first step, after deciding upon the type of organization, should be the selection of a competent man to take charge of the introduction of the new system; and the manager should think himself fortunate if he can get such a man at almost any price, since the task is a difficult and thankless one and but few men can be found who possess the necessary information coupled with the knowledge of men, the nerve, and the tact required for success in this work. The manager should keep himself free as far as possible from all active part in the introduction of the new

system. While changes are going on it will require his entire energies to see that there is no falling off in the efficiency of the old system and that the quality and quantity of the output is kept up. The mistake which is usually made when a change in system is decided upon is that the manager and his principal assistants undertake to make all of the improvements themselves during their spare time, with the common result that weeks, months and years go by without anything great being accomplished. The respective duties of the manager and the man in charge of improvement, and the limits of the authority of the latter should be clearly defined and agreed upon, always bearing in mind that responsibility should invariably be accompanied by its corresponding measure of authority.

The worst mistake that can be made is to refer to any part of the new system as being "on trial." Once a given step is decided upon, all parties must be made to understand that it will go whether any one around the place likes it or not. In making changes in system the things that are given a "fair trial" fail, while the things that "must go," go all right.

297. To decide where to begin is a perplexing and bewildering problem which faces the reorganizer in management when he arrives in a large establishment. In making this decision, as in taking each subsequent step, the most important consideration, which should always be first in the mind of the reformer, is "what effect will this step have upon the workmen?" Through some means (it would almost appear some especial sense), the workman seems to scent the approach of a reformer even before his arrival in town. Their suspicions are thoroughly aroused, and they are on the alert for sweeping changes which are to be against their interests and which they are prepared to oppose from the start. The first changes, therefore, should be such as to allay the suspicions of the men and convince them by actual contact that the reforms are after all rather harmless. Such improvements then as directly affect the workmen least should be started first. At the same time it must be remembered that the whole operation is of necessity so slow that the new system should be started at as many points as possible, and constantly pushed as hard as possible. A start can be made at once along all of the following lines:

298. 1. The introduction of standards throughout the works and office.

299. 2. The scientific study of "unit times" along several different lines.

300. 3. A complete analysis of the pulling, feeding power and the proper speeding of the various machine tools throughout the place with a view of making a slide rule for properly running each machine.

301. 4. The work of establishing the system of time cards by means of which ultimately all of the desired information will be conveyed from the men to the planning room.

302. 5. Overhauling the stores issue and receiving system so as to establish a complete running balance of materials.

303. 6. Ruling and printing the various blanks that will be required for shop returns and reports, time cards, instruction cards, expense sheets, cost sheets, pay sheet, and balance records, store room, tickler and maintenance of standards, system and plant, etc., and starting such functions of the planning room as do not directly affect the men.

304. If the works is a large one, the man in charge of introducing the system should appoint a special assistant in charge of each of the above functions just as an engineer designing a new plant would start a number of draftsmen to work upon the various elements of construction. Several of these assistants will be brought into close contact with the men, who will in this way gradually get used to seeing changes going on and their suspicion, both of the new men and the methods, will have been allayed to such an extent before any changes which seriously affect them are made, that little or no determined opposition on their part need be anticipated. The most important and difficult task of the organizer will be that of selecting and training the various functional foremen who are to lead and instruct the workmen, and his success will be measured principally by his ability to mould and teach these men. They cannot be found, they must be made. They must be instructed in their new functions largely, in the beginning at least, by the organizer himself; and this instruction, to be effective, should be mainly in actually doing the work. Explanation and theory will go a little way, but actual doing is needed to carry conviction. To illustrate: For nearly two and one-half years in the large shop of the Bethlehem Steel Company, one speed boss after another was instructed in the art of cutting metals fast on a large motor-driven lathe which was especially fitted to run at any desired speed

within a very wide range. The work done in this machine was entirely connected, either with the study of cutting tools or the instruction of speed bosses. It was most interesting to see these men, principally either former gang bosses or the best workmen, gradually change from their attitude of determined and positive opposition to that in most cases of enthusiasm for, and earnest support of, the new methods. It was actually running the lathe themselves according to the new method and under the most positive and definite orders that produced the effect. The writer himself ran the lathe and instructed the first few bosses. It required from three weeks to two months for each man. Perhaps the most important part of the gang boss's and foreman's education lies in teaching them to promptly obey orders and instructions received not only from the superintendent or some official high in the company, but from any member of the planning room whose especial function it is to direct the rest of the works in his particular line; and it may be accepted as an unquestioned fact that no gang boss is fit to direct his men until after he has learned to promptly obey instructions received from any proper source, whether he likes his instructions and the instructor or not, and even although he may be convinced that he knows a much better way of doing the work. The first step is for each man to learn to obey the laws as they exist, and next, if the laws are wrong, to have them reformed in the proper way.

305. In starting to organize even a comparatively small shop, containing say from 75 to 100 men, it is best to begin by training in the full number of functional foremen, one for each function, since it must be remembered that about two out of three of those who are taught this work either leave of their own accord or prove unsatisfactory; and in addition, while both the workmen and bosses are adjusting themselves to their new duties, there are needed fully twice the number of bosses as are required to carry on the work after it is fully systematized.

306. Unfortunately, there is no means of selecting in advance those out of a number of candidates for a given work who are likely to prove successful. Many of those who appear to have all of the desired qualities, and who talk and appear the best, will turn out utter failures, while on the other hand, some of the most unlikely men rise to the top. The fact is, that the more attractive qualities of good manners, education, and even special training and skill, which are more apparent on the surface, count for less in an

executive position than the grit, determination and bulldog endurance and tenacity that knows no defeat and comes up smiling to be knocked down over and over again.

307. The two qualities which count most for success in this kind of executive work are grit and what may be called "constructive imagination"—the faculty which enables a man to use the few facts that are stored in his mind in getting around the obstacles that oppose him, and in building up something useful in spite of them; and unfortunately, the presence of these qualities, together with honesty and common sense, can only be proved through an actual trial at executive work. As we all know, success at college, or in the technical school, does not indicate the presence of these qualities, even though the man may have worked hard. Mainly, it would seem, because the work of obtaining an education is principally that of absorption and assimilation; while that of active practical life, is principally the direct reverse, namely that of giving out.

308. In selecting men to be tried as foremen, or in fact for any position throughout the place, from the day laborer up, one of two different types of men should be chosen, according to the nature of the work to be done. For one class of work, men should be selected who are too good for the job; and for the other class of work, men who are barely good enough.

309. If the work is of a routine nature, in which the same operations are likely to be done over and over again, with no great variety, and in which there is no apparent prospect of a radical change being made, perhaps through a term of years, even though the work itself may be complicated in its nature, a man should be selected whose abilities are barely equal to the task. Time and training will fit him for his work, and since he will be better paid than in the past, and will realize that he has been given the chance to make his abilities yield him the largest return—all of the elements for promoting contentment will be present; and those men who are blessed with cheerful dispositions will become satisfied and remain so. Of course, a considerable part of mankind is so born or educated, that permanent contentment is out of the question. No one, however, should be influenced by the discontent of this class.

310. If the work to be done is of great variety—particularly if improvements in methods are to be anticipated—throughout the period of active organization the men engaged in systematiz-

ing should be too good for their jobs. For such work, men should be selected whose mental calibre and attainments will fit them, ultimately at least, to command higher wages than can be afforded on the work which they are at. It will prove a wise policy to promote such men, both to better positions and pay, when they have shown themselves capable of accomplishing results, and the opportunity offers. The results which these high-classed men will accomplish, and the comparatively short time which they will take in organizing, will much more than pay for the expense and trouble later on, of training other men, cheaper and of less capacity, to take their places. In many cases, however, gang bosses and men will develop faster than new positions open for them. When this occurs, it will pay employers well to find them positions in other works, either with better pay, or larger opportunities; not only as a matter of kindly feeling and generosity toward their men, but even more with the object of promoting the best interests of their own establishments. For one man lost in this way, five will be stimulated to work to the very limit of their abilities, and will rise ultimately to take the place of the man who has gone, and the best class of men will apply for work where these methods prevail. But few employers, however, are sufficiently broad-minded to adopt this policy. They dread the trouble and temporary inconvenience incident to training in new men.

311. Our president, Mr. James M. Dodge, is one of the few men with whom the writer is acquainted who has been led by his kindly instincts, as well as by a far-sighted policy, to treat his employees in this way; and this, together with the personal magnetism and influence which belong to men of his type, has done much to render his shop one of the model establishments of the country, certainly as far as the relations of employer and men are concerned.

312. On the other hand, this policy of promoting men and finding them new positions has its limits. No worse mistake can be made than that of allowing an establishment to be looked upon as a training school, to be used mainly for the education of many of its employees. All employees should bear in mind that each shop exists, first, last, and all the time, for the purpose of paying dividends to its owners. They should have patience, and never lose sight of this fact. And no man should expect promotion until after he has trained his successor to take his place. The

writer is quite sure that in his own case, as a young man, no one element was of such assistance to him in obtaining new opportunities as the practice of invariably training another man to fill his position before asking for advancement.

313. The first of the functional foremen to be brought into actual contact with the men should be the inspector; and the whole system of inspection, with its proper safeguards, should be in smooth and successful operation before any steps are taken toward stimulating the men to a larger output; otherwise an increase in quantity will probably be accompanied by a falling off in quality.

314. Next choose for the application of the two principal functional foremen, viz., the speed boss and the gang boss, that portion of the work in which there is the largest need of, and opportunity for, making a gain. It is of the utmost importance that the first combined application of time study, slide rules, instruction cards, functional foremanship, and a premium for a large daily task should prove a success both for the workmen and for the company, and for this reason a simple class of work should be chosen for a start. The entire efforts of the new management should be centred on one point, and continue there until unqualified success has been attained.

315. When once this gain has been made, a peg should be put in which shall keep it from sliding back in the least; and it is here that the task idea with a time limit for each job will be found most useful. Under ordinary piece work, or the Towne-Halsey plan, the men are likely at any time to slide back a considerable distance without having it particularly noticed either by them or the management. With the task idea, the first falling off is instantly felt by the workman through the loss of his day's bonus, or his differential rate, and is thereby also forcibly brought to the attention of the management.

316. There is one rather natural difficulty which arises when functional foremanship is first introduced. Men who were formerly either gang bosses, or foremen, are usually chosen as functional foremen, and these men, when they find their duties restricted to their particular functions, while they formerly were called upon to do everything, at first feel dissatisfied. They think that their field of usefulness is being greatly contracted. This is, however, a theoretical difficulty, which disappears when they really get into the full swing of their new positions. In fact

the new position demands an amount of special information, forethought, and a clear-cut, definite responsibility that they have never even approximated in the past, and which is amply sufficient to keep all of their best faculties and energies alive and fully occupied. It is the experience of the writer that there is a great commercial demand for men with this sort of definite knowledge, who are used to accepting real responsibility and getting results; so that the training in their new duties renders them more instead of less valuable.

317. As a rule, the writer has found that those who were growling the most, and were loudest in asserting that they ought to be doing the whole thing, were only one-half or one-quarter performing their own particular functions. This desire to do everyone's else work in addition to their own generally disappears when they are held to strict account in their particular line, and are given enough work to keep them hustling.

318. There are many people who will disapprove of the whole scheme of a planning department to do the thinking for the men, as well as a number of foremen to assist and lead each man in his work, on the ground that this does not tend to promote independence, self-reliance and originality in the individual. Those holding this view, however, must take exception to the whole trend of modern industrial development; and it appears to the writer that they overlook the real facts in the case.

319. It is true, for instance, that the planning room, and functional foremanship, render it possible for an intelligent laborer or helper in time to do much of the work now done by a machinist. Is not this a good thing for the laborer and helper? He is given a higher class of work, which tends to develop him and gives him better wages. In the sympathy for the machinist the case of the laborer is overlooked. This sympathy for the machinist is, however, wasted, since the machinist, with the aid of the new system, will rise to a higher class of work which he was unable to do in the past, and in addition, divided or functional foremanship will call for a larger number of men in this class, so that men, who must otherwise have remained machinists all their lives, will have the opportunity of rising to a foremanship.

320. The demand for men of originality and brains was never so great as it is now, and the modern subdivision of labor, instead of dwarfing men, enables them all along the line to rise to a higher plane of efficiency, involving at the same time more brain

work and less monotony. The type of man who was formerly a day laborer, digging dirt, is now for instance making shoes in a shoe factory, and dirt handling is done by Italians or Hungarians.

321. After the planning room with functional foremanship has accomplished its most difficult task, of teaching the men how to do a full day's work themselves, and also how to get it out of their machines steadily, then, if desired, the number of non-producers can be diminished, preferably, by giving each type of functional foreman more to do in his specialty; or in the case of a very small shop, by combining two different functions in the same man. The former expedient is, however, much to be preferred to the latter. There need never be any worry about what is to become of those engaged in systematizing after the period of active organization is over. The difficulty will still remain even with functional foremanship; that of getting enough good men to fill the positions, and the demand for competent gang bosses will always be so great that no good boss need look for a job.

322. Of all the farces in management the greatest is that of an establishment organized along well planned lines, with all of the elements needed for success, and yet which fails to get either output or economy. There must be some man or men present in the organization who will not mistake the form for the essence, and who will have brains enough to find out those of their employees who "get there," and nerve enough to make it unpleasant for those who fail, as well as to reward those who succeed. No system can do away with the need of real men. Both system and good men are needed, and after introducing the best system, success will be in proportion to the ability, consistency and respected authority of the management.

323. In a paper of this sort, it would be manifestly improper to discuss all of the details which go toward making the system a success. Some of them are of such importance as to render at least a brief reference to them necessary. And first among these comes the study of "unit times."

324. This, as already explained, is the most important element of the system advocated by the writer. Without it, the definite, clear-cut directions given to the workman, and the assigning of a full, yet just, daily task, with its premium for success, would be impossible; and the arch without the keystone would fall to the ground.

325. In 1883, while foreman of the machine shop of the Midvale Steel Company of Philadelphia, it occurred to the writer that it was simpler to time with a stop watch each of the elements of the various kinds of work done in the place, and then find the quickest time in which each job could be done by summing up the total times of its component parts, than it was to search through the time records of former jobs and guess at the proper time and price. After practising this method of time study himself for about a year, as well as circumstances would permit, it became evident that the system was a success. The writer then established the time-study and rate-fixing department, which has given out piece work prices in the place ever since.

326. This department far more than paid for itself from the very start; but it was several years before the full benefits of the system were felt, owing to the fact that the best methods of making and recording time observations, as well as of determining the maximum capacity of each of the machines in the place, and of making working tables and time tables, were not at first adopted.

327. It has been the writer's experience that the difficulties of scientific time study are underestimated at first, and greatly overestimated after actually trying the work for two or three months. The average manager, who decides to undertake the study of "unit times" in his works, fails at first to realize that he is starting a new art or trade. He understands, for instance, the difficulties which he would meet with in establishing a drafting room, and would look for but small results at first, if he were to give a bright man the task of making drawings who had never worked in a drafting room, and who was not even familiar with drafting implements and methods, but he entirely underestimates the difficulties of this new trade.

328. The art of studying "unit times" is quite as important and as difficult as that of the draftsman. It should be undertaken seriously, and looked upon as a profession. It has its own peculiar implements and methods, without the use and understanding of which progress will necessarily be slow, and in the absence of which there will be more failures than successes scored at first.

329. When, on the other hand, an energetic, determined man goes at "time study" as if it were his life's work, with the determination to succeed, the results which he can secure are little short of astounding. The difficulties of the task will be felt at once, and so strongly by any one who undertakes it, that it seems important

to encourage the beginner by giving at least one illustration of what has been accomplished.

330. Mr. Sanford E. Thompson, C.E., of Newton Highlands, Mass., started in 1896 with but small help from the writer, except as far as the implements and methods are concerned, to study the time required to do all kinds of work in the building trades. In six years he has made a complete study of eight of the most important trades—excavation, masonry, bricklaying (including sewer-work and paving), carpentry, concrete and cement work, lathing and plastering, slating and roofing and rock quarrying. He took every stop watch observation himself, and then with the aid of two comparatively cheap assistants, worked up and tabulated all of his data ready for the printer. The magnitude of this undertaking will be appreciated when it is understood that the tables and descriptive matter for one of these trades alone take up about 250 pages. Mr. Thompson and the writer are both engineers, but neither of us was especially familiar with the above trades and this work could not have been accomplished in a lifetime without the study of elementary units with a stop watch.

331. In the course of this work, Mr. Thompson has developed what are in many respects the best implements in use, and with his permission some of them will be described. The blank form or note sheet used by Mr. Thompson, shown in Fig. 293, contains essentially:

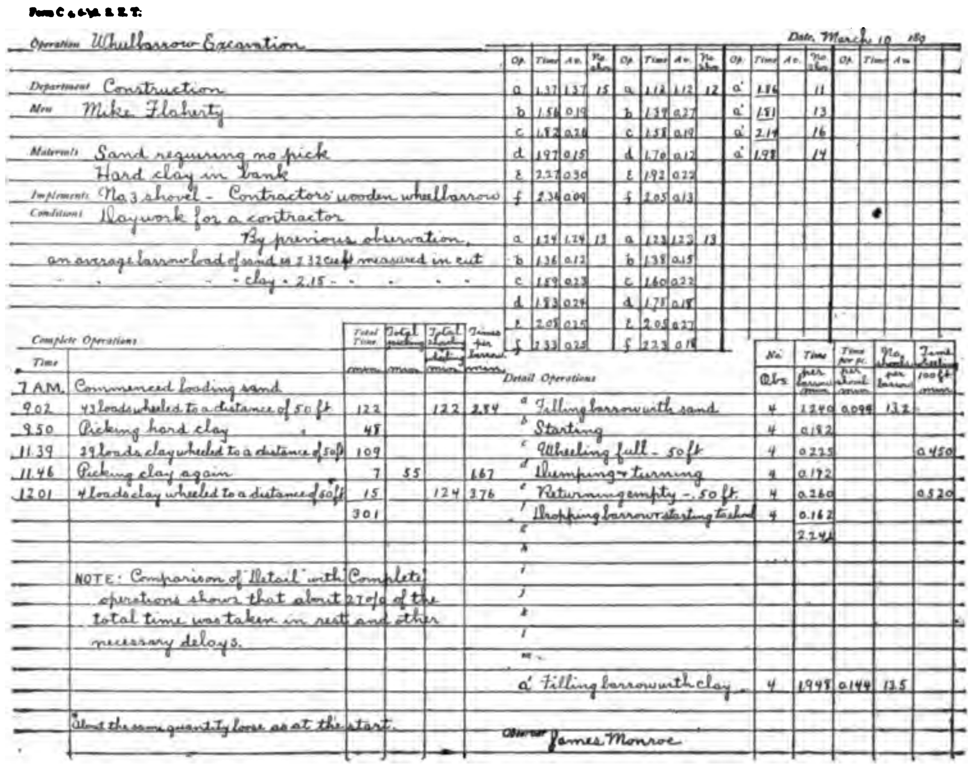
(1) Space for the description of the work and notes in regard to it.

(2) A place for recording the total time of complete operations —that is, the gross time including all necessary delays, for doing a whole job or large portions of it.

(3) Lines for setting down the "Detail Operations," or "units" into which any piece of work may be divided, followed by columns for entering the averages obtained from the observations.

(4) Squares for recording the readings of the stop watch when observing the times of these elements. (If these squares are filled, additional records can be entered on the back.) The size of the sheets, which should be of best quality ledger paper, is 8¾ inches wide by 7 inches long, and by folding in the centre they can be conveniently carried in the pocket, or placed in a case containing one or more stop watches.

332. This case, or "watch book," is another device of Mr. Thompson's. It consists of a frame work, containing concealed in



Form C 4-6-½ 8 8 T.

Operation Wheelbarrow Excavation

Date, March 10 189

Department Construction

Men Mike Flaherty

Materials Sand requiring no pick
Hard clay in bank

Implements No 3 shovel - Contractors' wooden wheelbarrow

Conditions Daywork for a contractor

By previous observation,
an average barrow load of sand is 3.32 cu ft measured in cut
" " " " clay " 2.15 " " " "

Op.	Time	Av.	No. sho.	Op.	Time	Av.	No. sho.	Op.	Time	Av.	No. sho.	Op.	Time	Av.
a	1.37	1.37	15	a	1.12	1.12	12	a'	1.86		11			
b	1.56	0.19		b	1.39	0.27		a'	1.81		13			
c	1.82	0.26		c	1.58	0.19		a'	2.14		16			
d	1.97	0.15		d	1.70	0.12		a'	1.98		14			
e	2.27	0.30		e	1.92	0.22								
f	2.36	0.09		f	2.05	0.13								
a	1.24	1.24	13	a	1.23	1.23	13							
b	1.36	0.12		b	1.38	0.15								
c	1.59	0.23		c	1.60	0.22								
d	1.83	0.24		d	1.78	0.18								
e	2.08	0.25		e	2.05	0.27								
f	2.33	0.25		f	2.23	0.18								

Complete Operations

Time		Total Time min.	Total picking min.	Total wheeling dist. min.	Time per barrow min.
7 AM.	Commenced loading sand				
9.02	43 loads wheeled to a distance of 50 ft	122		122	2.84
9.50	Picking hard clay	48			
11.39	29 loads clay wheeled to a distance of 50 ft	109			
11.46	Picking clay again	7	55		1.67
12.01	4 loads clay wheeled to a distance of 50 ft	15		124	3.76
		301			

NOTE: Comparison of "Detail" with "Complete" operations shows that about 27% of the total time was taken in rest and other necessary delays.

About the same quantity loose as at the start.

Detail Operations

		No. Obs.	Time per barrow min.	Time per pc. per shovel min.	No. shovels per barrow	Time wheeling 100 ft. min.
a	Filling barrow with sand	4	1.240	0.094	13.2	
b	Starting	4	0.182			
c	Wheeling full - 50 ft	4	0.225			0.450
d	Dumping & turning	4	0.172			
e	Returning empty - 50 ft.	4	0.260			0.520
f	Dropping barrow & starting to shovel	4	0.162			
g			2.241			
h						
i						
j						
k						
l						
m						
a'	Filling barrow with clay	4	1.948	0.144	13.5	

Observer James Monroe

FIG. 298.

it, one, two or three watches, whose stop and start movements can be operated by pressing with the fingers of the left hand upon the proper portion of the cover of the note-book without * the knowledge of the workman who is being observed. The frame is bound in a leather case resembling a pocket note-book, and has a place

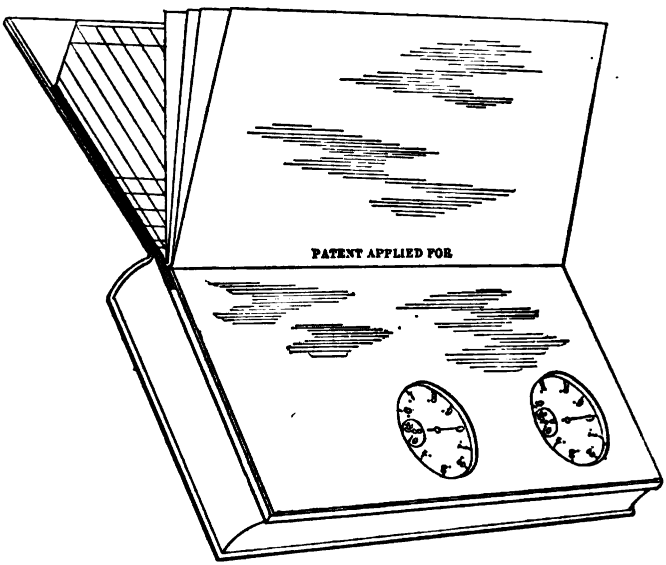


FIG. 294.

for the note sheets described. A sketch of this watch-book is shown in Fig. 294. The operation selected for illustration on the note sheet is the excavation of earth with wheelbarrows, and the values given are fair averages of actual contract work where the wheelbarrow man fills his own barrow. It is obvious that similar methods of analyzing and recording may be applied to

* The writer does not believe at all in the policy of spying upon the workman when taking time observations for the purpose of time study. If the men observed are to be ultimately affected by the results of these observations, it is generally best to come out openly, and let them know that they are being timed, and what the object of the timing is. There are many cases, however, in which telling the workman that he was being timed in a minute way would only result in a row, and in defeating the whole object of the timing; particularly when only a few time units are to be studied on one man's work, and when this man will not be personally affected by the results of the observations. In these cases, the watch book of Mr. Thompson, holding the watches in the cover, is especially useful. A good deal of judgment is required to know when to time openly, or the reverse.

work ranging from unloading coal to skilled labor on fine machine tools.

333. The method of using the note sheets for timing a workman is as follows:

After entering the necessary descriptive matter at the top of the sheet, divide the operation to be timed into its elementary units, and write these units one after another under the heading "Detail Operations." (If the job is long and complicated, it may

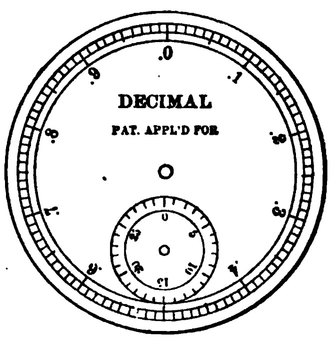


FIG. 295.

be analyzed while the timing is going on, and the elementary units entered then instead of beforehand.) In wheelbarrow work as illustrated in the example shown on the note sheet (Fig. 293), the elementary units consist of "filling barrow," "starting" (which includes throwing down shovel and lifting handles of barrow), "wheeling full," etc. These units might have been further subdivided—the first one into time for loading one shovelful, or still further into the time for filling and the time for emptying each shovelful.

334. The letters a, b, c, etc., which are printed, are simply for convenience in designating the elements.

335. We are now ready for the stop watch, which, to save clerical work, should be provided with a decimal dial similar to that shown in Fig. 295. The method of using this and of recording the times depends upon the character of the time observations. In all cases, however, the stop watch times are recorded in the columns headed "Time" at the top of the right-hand half of the note sheet. These columns are the only place on the face of the sheet where stop-watch readings are to be entered. If more

space is required for these times, they should be entered on the back of the sheets. The rest of the figures (except those on the left-hand page, which may be taken from an ordinary timepiece) are the results of calculation, and may be made in the office by any clerk.

336. As has been stated, the method of recording the stop-watch observations depends upon the work which is being observed. If the operation consists of the same element repeated over and over, the time of each may be set down separately; or, if the element is very small, the total time of, say, ten may be entered as a fraction, with the time for all ten observations as the numerator, and the number of observations for the denominator.

337. In the illustration, the operation consists of a series of elements. In such a case, the letters designating each elementary unit are entered under the columns "Op.," the stop-watch is thrown to zero, and started as the man commences to work. As each new division of the operation (that is, as each elementary unit or "unit time") is begun, the time is recorded. During any special delay the watch may be stopped, and started again from the same point, although, as a rule, Mr. Thompson advocates allowing the watch to run continuously, and enters the time of such a stop, designating it for convenience by the letter "Y."

338. In the case we are considering, two kinds of materials were handled—sand and clay. The time of each of the unit times, except the filling, is the same for both sand and clay; hence, if we have sufficient observations on either one of the materials, the only element of the other which requires to be timed is the loading. This illustrates one of the merits of the elementary system.

339. The column "Av." is filled from the preceding column. The figures thus found are the actual net times of the different "unit times." These unit times are averaged and entered in the "Time" column, on the lower half of the right-hand page, preceded, in the "No." column, by the number of observations which have been taken of each unit. These times, combined and compared with the gross times on the left-hand page, will determine the percentage lost in resting and other necessary delays. A convenient method for obtaining the time of an operation, like picking, in which the quantity is difficult to measure, is suggested by the records on the left-hand page.

340. The percentage of the time taken in rest and other necessary delays, which is noted on the sheet as, in this case, about 27

per cent., is obtained by a comparison of the average net "time per barrow" on the right with the "time per barrow" on the left. The latter is the quotient of the total time shovelling and wheeling divided by the number of loads wheeled.

341. It must be remembered that the example given is simply for illustration. To obtain accurate average times, for any item of work under specified conditions, it is necessary to take observations upon a number of men, each of whom is at work under conditions which are comparable. The total number of observations which should be taken of any one elementary unit depends upon its variableness, and also upon its frequency of occurrence in a day's work.

342. An expert observer can, on many kinds of work, time two or three men at the same time with the same watch, or he can operate two or three watches—one for each man. A note sheet can contain only a comparatively few observations. It is not convenient to make it of larger size than the dimensions given, when a watch-book is to be used, although it is perfectly feasible to make the horizontal rulings 8 lines to the inch instead of 5 lines to the inch as on the sample sheet. There will have to be, in almost all cases, a large number of note sheets on the same subject. Some system must be arranged for collecting and tabulating these records. On Fig. 296 is shown a portion of the form or plate used for tabulating. The sketch shows for lack of space merely the left-hand end of the plate. The total length should be either 16 or 22 inches. The height of the plate is 10½ inches. With these dimensions a plate may be folded and filed with ordinary letter sheets (8 inches by 10½ inches). The ruling which has been found most convenient is for the vertical divisions 3 columns to 1¼ inches, while the horizontal lines are ruled 6 to the inch. The columns may, or may not, have printed headings.

343. The data from the note sheet in Fig. 293 is copied on to the table for illustration. The first columns of the table are descriptive. The rest of them are arranged so as to include all of the "unit times," with any other data which are to be averaged or used when studying the results. Data upon only two elements are shown—that of "loading barrow" and "starting"; the remainder are entered in a similar way in the columns which follow, and at the extreme right of the sheet (not shown) the gross times, including rest and necessary delay, are recorded and the percentages of rest are calculated.

EARTHWORK-BARROWS.

Note Sheet.	Department.	Men.	Implements.	Description.	Loading Barrow.							Remarks.	Starting.	
					Material.	Capacity of a barrow, cu. ft.	No. shovels per barrow.	Capacity of a shovel, cu. ft.	Time filling barrow, minutes.	Time per shovel, minutes.	Time per cu. ft., min.		No. Obs.	Time per barrow, min.
3-10-03	Construction.	Flaherty.	No. 3 shovel, contractor's barrow.	Wheeeler loading barrow.	Sand. Clay.		18.2 13.5		1.240 1.948	0.094 0.144			4	0.182

FIG. 296.

344. Formulæ are convenient for combining the elements. For simplicity, in the example of barrow excavation, each of the " unit times " may be designated by the same letters used on the note sheet (Fig. 293) although in practice each element can best be designated by the initial letters of the words describing it.

345. Let

a = time filling a barrow with any material.
b = time preparing to wheel.
c = time wheeling full barrow 100 feet.
d = time dumping and turning.
e = time returning 100 feet with empty barrow.
f = time dropping barrow and starting to shovel.
p = time loosening one cubic yard with the pick.
P = percentage of a day required for rest and necessary delays.
L = load of a barrow in cubic feet.
B = time per cubic yard picking, loading and wheeling any given kind of earth to any given distance when the wheeler loads his own barrow.

346. Then

$$B = \left(p + \left[a + b + d + f + \frac{\text{distance hauled}}{100}(c + e)\right]\frac{27}{L}\right)(1 + P) \quad . \quad . \quad (1)$$

347. This general formula for barrow work can be simplified by choosing average values for the constants, and substituting numerals for the letters now representing them. Substituting the average values from the note sheet on Fig. 293, our formula becomes:

$$B = \left(p + \left[a + 0.18 + 0.17 + 0.16 + \frac{\text{distance hauled}}{100}(0.22 + 0.26)\right]\frac{27}{L}\right) 1.27,$$

or

$$B = \left(p + [a + 0.51 + (0.0048)\text{ distance hauled}]\frac{27}{L}\right) 1.27 \quad . \quad . \quad (2)$$

348. Formula 2 is applicable to any kind of earth hauled by men working at the speeds recorded on the note sheet to any distance.

349. For sand, still using the values given on the note sheet (Fig. 1).

$$B = \left(0 + [1.24 + 0.51 + 0.0048 \text{ (distance hauled)}]\frac{27}{2.32}\right) 1.27,$$

or

$$B = 25.86 + 0.071 \text{ (distance hauled)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

For a 50-foot haul:

$B = 25.86 + 0.071\ (50) = 29.4$ min. as the time for one man to load and wheel one cubic yard of sand a distance of 50 feet.

350. In classes of work where the percentage of rest varies with the different elements of an operation, it is most convenient to correct all of the elementary times by the proper percentages before combining them. Sometimes after having constructed a general formula, it may be solved by setting down the substitute numerical values in a vertical column for direct addition.

351. On Fig. 297 is shown a table to illustrate times for throwing earth to different distances and different heights. It will be seen that for each special material the time for filling shovel remains the same regardless of the distance to which it is thrown. Each kind of material requires a different time for filling the shovel. The time throwing one shovelful, on the other hand, varies with the length of throw, but for any given distance it is the same for all of the earths. If the earth is of such a nature that it sticks to the shovel, this relation does not hold. For the elements of shoveling we have therefore:

352.

s = time filling shovel and straightening up ready to throw.
t = time throwing one shovelful.
w = time walking one foot with loaded shovel.
w' = time returning one foot with empty shovel.
L = load of a shovel in cubic feet.
P = percentage of a day required for rest and necessary delays.
T = time for shovelling one cubic yard.

SHOVELLING EARTH IN AVERAGE [illegible]

EARTH PREVIOUSLY LOOSENED.—VOLUMES ARE BASED ON MEASUREMENT IN CUT.

Material.	Throw.		Length of walk.	Actual Continuous Work with no Allowance for Rest or other Stops.										Per cent. of rest.	Allowing for Rests and other Necessary Stops.		
	Vertical.	Horizontal.		Time to fill shovel.	Time to throw shovelful.	Time walking with load.	Time of back walk.	Total time of complete operation.	Volume of shovelful.	Weight of shovelful.	No. shovelfuls per minute.	No. cubic yards per hour.	No. pounds per hour.		No. shovelfuls per minute.	No. cubic yards per hour.	No. pounds per hour.
	Feet.	Feet.	Feet.	Minutes.	Minutes.	Minutes.	Minutes.	Minutes.	Cu. ft.	Lbs.	Shovels.	Cu. yds.	Lbs.	P. c.	Shovels.	Yards.	Lbs.
Sand or sandy loam.	4	5	......	0.078	0.031	....	....	0.104	0.16	16	9.6	3.4	9,230	30	7.4	2.6	7,100
	6	5	......	0.078	0.043	....	....	0.116	0.14	14	8.6	2.7	7,250	30	6.6	2.0	5,580
	8	5	......	0.078	0.056	....	....	0.129	0.11	11	7.8	1.9	5,120	30	6.0	1.4	3,940
	4	7½	......	0.078	0.043	....	....	0.116	0.14	14	8.6	2.7	7,350	30	6.6	2.1	5,580
	6	7½	......	0.078	0.056	....	....	0.129	0.12	12	7.8	2.1	5,590	30	6.0	1.6	4,300
	4	10	......	0.078	0.058	....	....	0.131	0.13	13	7.6	2.2	5,960	30	5.9	1.7	4,580
	6	10	......	0.078	0.076	....	....	0.149	0.11	11	6.7	1.6	4,440	30	5.2	1.3	3,420
	......	......	20	0.078	0.090	0.080	0.080	0.253	0.20	20.0	4.0	1.8	4,750	5	3.8	1.7	4,520
	......	......	30	0.078	0.090	0.120	0.120	0.333	0.20	20.0	3.0	1.3	3,600	5	2.9	1.3	3,480
Loam, gravelly.	4	5	......	0.092	0.031	....	....	0.123	0.14	15.8	8.1	2.5	7,700	30	6.2	2.0	5,920
	6	5	......	0.092	0.043	....	....	0.135	0.13	14.7	7.4	2.1	6,520	30	5.7	1.6	5,015
	8	5	......	0.092	0.056	....	....	0.148	0.10	11.8	6.8	1.5	4,580	30	5.2	1.2	3,530
	4	7½	......	0.092	0.043	....	....	0.135	0.13	14.7	7.4	2.1	6,510	30	5.7	1.6	5,010
	6	7½	......	0.092	0.056	....	....	0.148	0.11	12.4	6.8	1.6	5,030	30	5.2	1.3	3,870
	4	10	......	0.092	0.058	....	....	0.150	0.12	13.6	6.7	1.8	5,440	30	5.1	1.4	4,180
	6	10	......	0.092	0.076	....	....	0.168	0.10	11.8	6.0	1.3	4,080	30	4.6	1.0	3,100
	......	......	20	0.092	0.090	0.080	0.080	0.272	0.19	21.5	3.7	1.6	4,750	5	3.5	1.5	4,520
	......	......	30	0.092	0.020	0.120	0.120	0.352	0.19	21.5	2.8	1.2	3,670	5	2.7	1.1	3,490
Gravel, medium.	4	5	......	0.084	0.031	....	....	0.115	0.12	17.0	8.7	2.3	8,870	30	6.7	1.8	6,820
	6	5	......	0.084	0.043	....	....	0.127	0.10	14.2	7.9	1.8	6,720	30	6.0	1.8	5,170
	8	5	......	0.084	0.056	....	....	0.140	0.08	11.4	7.1	1.3	4,880	30	5.5	1.0	3,750
	4	7½	......	0.084	0.043	....	....	0.127	0.11	15.6	7.9	1.9	7,370	30	6.0	1.5	5,670
	6	7½	......	0.084	0.056	....	....	0.140	0.09	12.8	7.1	1.4	5,480	30	5.5	1.1	4,220
	4	10	......	0.084	0.058	....	....	0.142	0.10	14.2	7.0	1.6	6,000	30	5.4	1.2	4,620
	6	10	......	0.084	0.076	....	....	0.160	0.08	11.4	6.2	1.1	4,270	30	4.8	.8	3,280
	......	......	20	0.084	0.090	0.080	0.080	0.264	0.15	21.3	3.8	1.3	4,840	5	3.6	1.2	4,610
	......	......	30	0.084	0.090	0.120	0.120	0.344	0.15	21.3	2.9	1.0	3,720	5	2.8	0.9	3,540

FIG. 297.

353. Our formula, then, for handling anv earth after it is loosened, is:

$$T = \left([s + t + (w + w') \text{ distance carried}] \frac{27}{L}\right)(1 + P).$$

354. Where the material is simply thrown without walking, the formula becomes:

$$T = \left((s + t)\frac{27}{L}\right)(1 + P).$$

355. If weights are used instead of volumes:

$$\text{Time shovelling one ton} = \left((s + t)\frac{\text{No. of lbs. in one ton}}{\text{weight of one shovelful}}\right)(1 + P).$$

356. The writer has found the printed form shown on Fig. 6 useful in studying unit times in a certain class of the hand work done in a machine shop. This blank is fastened to a thin board held in the left hand and resting on the left arm of the observer. A stop-watch is inserted in a small compartment attached to the back of the board at a point a little above its centre; the face of the watch being seen from the front of the board through a small flap cut partly loose from the observation blank; while the watch is operated by the fingers of the left hand, the right hand of the operator is at all times free to enter the time observations on the blank. A pencil sketch of the work to be observed is made in the blank space on the upper left-hand portion of the sheet. In using this blank, of course, all attempt at secrecy is abandoned.

357. The mistake usually made by beginners is that of failing to note in sufficient detail the various conditions surrounding the job. It is not at first appreciated that the whole work of the time observer is useless if there is any doubt as to even one of these conditions. Such items, for instance, as the name of the man or men on the work, the number of helpers, and exact description of all of the implements used, even those which seem unimportant, such, for instance, as the diameter and length of bolts and the style of clamps used, the weight of the piece upon which work is being done, etc.

358. It is also desirable that, as soon as practicable after taking a few complete sets of time observations, the operator should be given the opportunity of working up one or two sets at least by

summing up the unit times and allowing the proper per cent. of rest, etc., and putting them into practical use, either by comparing his results with the actual time of a job which is known to be done in fast time, or by setting a time which a workman is to live up to.

359. The actual practical trial of the time student's work is most useful, both in teaching him the necessity of carefully noting the minutest details, and on the other hand convincing him of the practicability of the whole method, and in encouraging him in future work.

360. In making time observations, absolutely nothing should be left to the memory of the student. Every item, even those which appear self-evident, should be accurately recorded. The writer, and the assistant who immediately followed him, both made the mistake of not putting the results of much of their time study into use soon enough, so that many time observations which extended over a period of months were thrown away in most instances because of failure to note some apparently unimportant detail.

361. It may be needless to state that when the results of time observations are first worked up, it will take far more time to pick out and add up the proper unit times, and allow the proper percentages of rest, etc., than it originally did for the workman to do the job. This fact need not disturb the operator, however. It will be evident that the slow time made at the start is due to his lack of experience, and he must take it for granted that later many short-cuts can be found, and that a man with an average memory will be able with practice to carry all of the important time units in his head.

362. No system of time study can be looked upon as a success unless it enables the time observer, after a reasonable amount of study, to predict with accuracy how long it should take a good man to do almost any job in the particular trade, or branch of a trade, to which the time student has been devoting himself. It is true that hardly any two jobs in a given trade are exactly the same, and that if a time student were to follow the old method of studying and recording the whole time required to do the various jobs which came under his observation, without dividing them into their elements, he would make comparatively small progress in a lifetime, and at best would become a skilful guesser. It is, however, equally true that all of the work done in a given trade can be divided into a comparatively small number of elements or units, and that with proper implements and methods it is comparatively

easy for a skilled observer to determine the time required by a good man to do any one of these elementary units.

363. Having carefully recorded the time for each of these elements, it is a simple matter to divide each job into its elementary units, and by adding their times together, to arrive accurately at the total time for the job. The elements of the art which at first appear most difficult to investigate are the percentages which should be allowed, under different conditions, for rest and for accidental or unavoidable delays. These elements can, however, be studied with about the same accuracy as the others.

364. Perhaps the greatest difficulty rests upon the fact that no two men work at exactly the same speed. The writer has found it best to take his time observations on first-class men only, when they can be found; and these men should be timed when working at their best. Having obtained the best time of a first-class man, it is a simple matter to determine the percentage which an average man will fall short of this maximum.

365. It is a good plan to pay a first-class man an extra price while his work is being timed. When workmen once understand that the time study is being made to enable them to earn higher wages, the writer has found them quite ready to help instead of hindering him in his work. The division of a given job into its proper elementary units, before beginning the time study, calls for considerable skill and good judgment. If the job to be observed is one which will be repeated over and over again, or if it is one of a series of similar jobs which form an important part of the standard work of an establishment, or of the trade which is being studied, then it is best to divide the job into elements which are rudimentary. In some cases this subdivision should be carried to a point which seems at first glance almost absurd.

366. For example, in the case of the study of the art of shovelling earths, referred to in the table Fig. 5, it will be seen that handling a shovelful of dirt is subdivided into,

s = "Time filling shovel and straightening up ready to throw,"

and

t = "Time throwing one shovelful."

367. The first impression is that this minute subdivision of the work into elements, neither of which takes more than five or six seconds to perform, is little short of preposterous; yet if a rapid and thorough time study of the art of shovelling is to be made,

FRED. W. TAYLOR.

Form D. 109.

M A ITH SODA WATER.

	10th.		11th.		12th.	
ame	Was.	Should have been.	Was.	Should have been.	Was.	Should have been.

Ta, etc., should have Taken,

this subdivision simplifies the work, and makes time study quicker and more thorough.

368. The reasons for this are twofold:

(1) In the art of shovelling dirt, for instance, the study of fifty or sixty small elements, like those referred to above, will enable one to fix the exact time for many thousands of complete jobs of shovelling, constituting a very considerable proportion of the entire art.

(2) The study of single small elements is simpler, quicker, and more certain to be successful than that of a large number of elements combined. The greater the length of time involved in a single item of time study, the greater will be the likelihood of interruptions or accidents, which will render the results obtained by the observer questionable or even useless.

369. There is a considerable part of the work of most establishments that is not what may be called standard work, namely, that which is repeated many times. Such jobs as this can be divided for time study into groups, each of which contains several rudimentary elements. A division of this sort will be seen by referring to the data entered on face of card on Fig. 293.

370. In this case, instead of observing, first, the "time to fill a shovel," and then the time to "throw it into a wheelbarrow," etc., a number of these more rudimentary operations are grouped into the single operation of: a = "Time filling a wheelbarrow with any material," and studied as a whole.

371. Another illustration of the degree of subdivision which is desirable will be found by referring to blank on Fig. 298.

372. Where a general study is being made of the time required to do all kinds of hand work connected with and using machine tools, the items printed in detail should be timed singly.

373. When some special job, not to be repeated many times, is to be studied, then several elementary items can be grouped together and studied as a whole, in such groups for example as:

"Getting job ready to set."
"Setting work."
"Setting tool."
"Extra hand work."
"Removing work."

And in some cases even these groups can be further condensed.

374. An illustration of the time units which it is desirable to

sum up and properly record and index for a certain kind of lathe work is given in Fig. 299.

375. The writer has found that when some jobs are divided into their proper elements, certain of these elementary operations are so very small in time that it is difficult, if not impossible, to obtain accurate readings on the watch. In such cases, where the work consists of recurring cycles of elementary operations, that is, where a series of elementary operations is repeated over and over again, it is possible to take sets of observations on two or more of the successive elementary operations which occur in regular order, and from the times thus obtained to calculate the time of each element. An example of this is the work of loading pig iron on to bogies. The elementary operations or elements consist of:

(1) Picking up a pig.
(2) Walking with it to the bogie.
(3) Throwing or placing it on the bogie.
(4) Returning to the pile of pigs.

376. Here the length of time occupied in picking up the pig and throwing or placing it on the bogie is so small as to be difficult to time, but observations may be taken successively on the elements in sets of three. We may, in other words, take one set of observations upon the combined time of the three elements numbered 1, 2, 3; another set upon elements 2, 3, 4; another set upon elements 3, 4, 1, and still another upon the set 4, 1, 2. By algebraic equations we may solve the values of each of the separate elements.

377. If we take a cycle consisting of five (5) elementary operations, a, b, c, d, e, and let observations be taken on three of them at a time, we have the equations:

$$\begin{aligned} a + b + c &= A \\ b + c + d &= B \\ c + d + e &= C \\ d + e + a &= D \\ e + a + b &= E \\ A + B + C + D + E &= S. \end{aligned}$$

378. We may solve and obtain:

$$\begin{aligned} a &= A + D - \tfrac{1}{3}S \\ b &= B + E - \tfrac{1}{3}S \\ c &= C + A - \tfrac{1}{3}S \\ d &= D + B - \tfrac{1}{3}S \\ e &= E + C - \tfrac{1}{3}S. \end{aligned}$$

5,981. 7-16-07 1500.

The Midvale Steel Co.

Form D—124. Machine Shop,..18........

Estimates for Work on Lathes.

OPERATIONS CONNECTED WITH PREPARING TO MACHINE WORK ON LATHES AND WITH REMOVING WORK TO FLOOR AFTER IT HAS BEEN MACHINED

OPERATIONS.	TIME IN MINUTES.	
Putting chain on, Work on Floor,		
" " Work on Centres,		
Taking off chain, Work on Floor,		
" " Work on Centres,		
Putting on Carrier,		
Taking off "		
Lifting Work to Shears,		
Getting Work on Centres,		
Lifting W'k from Centres to Floor,		
Turning Work, end for end,		
Adjusting Soda Water,		
Stamping,		
Centre-punching,		
Trying Trueness with Chalk,		
" with Callipers,		
" with Gauge,		
Putting in Mandrel,		
Taking out "		
Putting in Plug Centres,		
Taking out "		
Putting in False Centres,		
Taking out "		
Putting on Spiders,		
Taking off "		
Putting on Follow Rest,		
Taking off "		
Putting on Face Plate,		
Taking off "		
Putting on Chuck,		
Taking off "		
Laying out,		
Changing Tools,		
Putting in Packing,		
Cut to Cut,		
Learning what is to be done,		
Considering how to Clamp,		
Oiling up,		
Cleaning Machine,		
Changing Time Notes,		
Changing Tools at Tool Room,		
Shifting Work,		
Putting on Former,		
Taking off "		
Adjusting Feed,		
" Speed,		
" Poppet Head,		
" Screw Cutting Gear,		
SIGNED, TOTAL,		

Name,..

Sketch,.......................Number,.......................

Order,.......................Weight,.......................

Metal,.......................Heat No.......................

Tensile Strength,..........Chem. Comp..........

Per Cent. of Stretch,.......................................

HARDNESS, Class.......................

OPERATIONS CONNECTED WITH MACHINING WORK ON LATHES.

OPERATIONS.	Speed.	Feed.	Cut.	Tool.	Inches.	Minutes.
Turning Feed In,						
" "						
" Hand Feed,						
" "						
Boring Feed In,						
" "						
" Hand Feed,						
" "						
Starting Cut,						
" "						
Finishing Cut,						
" "						
Fillet,						
"						
"						
Collar,						
"						
Facing,						
"						
Slicing,						
"						
"						
Nicking,						
"						
Centring,						
"						
Filing,						
"						
Using Emery Cloth,						
" "						
TOTAL						

Machining—Two Heads Used,
" —One Head Used,
Hand Work,
Additional Allowance,

TOTAL TIME,
HIGH RATE,
LOW RATE.

Remarks,

Time actually taken,

FIG. 299.

379. The writer was surprised to find, however, that while in some cases these equations were readily solved, in others they were impossible of solution. My friend, Mr. Carl J. Barth, when the matter was referred to him, soon developed the fact that the number of elements of a cycle which may be observed together is subject to a mathematical law, which is expressed by him as follows:

The number of successive elements observed together must be prime to the total number of elements in the cycle.

380. Namely, the number of elements in any set must contain no factors; that is, must be divisible by no numbers which are contained in the total number of elements. The following table is, therefore, calculated by Mr. Barth showing how many operations may be observed together in various cases. The last column gives the number of observations in a set which will lead to the determination of the results with the minimum of labor.

No. of Operations in the Cycle.	No. of Operations that may be observed together.	No. observed together that lead to a minimum of labor or is otherwise preferable.
3	2	2
4	3	3
5	2, 3, or 4	3 or 4
6	5	5
7	2, 3, 4, 5, or 6	4 or 6
8	3, 5, or 7	5 or 7
9	2, 4, 5, 7, or 8	5 or 8
10	3, 7, or 9	7 or 9
11	2, 3, 4, 5, 6, 7, 8, 9, or 10	5 or 10
12	5, 7, or 11	7 or 11

381. When time study is undertaken in a systematic way, it becomes possible to do greater justice in many ways both to employers and workmen than has been done in the past. For example, we all know that the first time that even a skilled workman does a job it takes him a longer time than is required after he is familiar with his work, and used to a particular sequence of operations. The practised time student can not only figure out the time in which a piece of work should be done by a good man, after he has become familiar with this particular job through practice, but he should also be able to state how much more time would be required to do the same job when a good man goes at it for the first time; and this knowledge would make it possible to assign one time limit and price for new work, and a smaller time and price for the same job after being repeated, which is much more fair and just to both parties than the usual fixed price.

382. As the writer has said several times, the difference between the best speed of a first-class man and the actual speed of the average man is very great. One of the most difficult pieces of work which must be faced by the man who is to set the daily tasks is to decide just how hard it is wise for him to make the task. Shall it be fixed for a first-class man, and if not, then at what point between the first-class and the average?

383. One fact is clear, it should always be well above the performance of the average man, since men will invariably do better if a bonus is offered them than they have done without this incentive.

384. The writer has, in almost all cases, solved this part of the problem by fixing a task which required a first-class man to do his best, and then offering a good round premium. When this high standard is set it takes longer to raise the men up to it. But it is surprising after all how rapidly they develop.

385. The precise point between the average and the first-class, which is selected for the task, should depend largely upon the labor market in which the works is situated. If the works were in a fine labor market, such, for instance, as that of Philadelphia, there is no question that the highest standard should be aimed at. If, on the other hand, the shop required a good deal of skilled labor, and were situated in a small country town, it might be wise to aim rather lower. There is a great difference in the labor markets of even some of the adjoining states in this country, and in one instance in which the writer was aiming at a high standard in organizing a works, he found it necessary to import almost all of his men from a neighboring state before meeting with success.

386. Whether the bonus is given only when the work is done in the quickest time or at some point between this and the average time, *in all cases* the instruction card should state the best time in which the work can be done by a first-class man. There will then be no suspicion on the part of the men when a longer "bonus time" is allowed, that the time student does not really know the possibilities of the case. For example, the instruction card might read:

Proper time.................... 65 minutes.
Bonus given first time job is done...108 minutes.

387. It is of the greatest importance that the man who has charge of assigning tasks should be perfectly straightforward in all

of his dealings with the men. Neither in this nor in any other branch of the management should a man make any pretence of having more knowledge than he really possesses. He should impress the workmen with the fact that he is dead in earnest, and that he fully intends to know all about it some day; but he should make no claim to omniscience, and should always be ready to acknowledge and correct an error if he makes one. This combination of determination and frankness establishes a sound and healthy relation between the management and men.

388. There is no class of work which cannot be profitably submitted to time study, by dividing it into its time elements, except such operations as take place in the head of the worker; and the writer has even seen a time study made of the speed of an average and first-class boy in solving problems in mathematics. Clerk work can well be submitted to time study, and a daily task assigned in work of this class which at first appears to be very miscellaneous in its character.

389. One of the needs of modern management is that of literature on the subject of time study. The writer quotes as follows from his paper on "A Piece Rate System," written in 1895:

390. "Practically the greatest need felt in an establishment wishing to start a rate-fixing department is the lack of data as to the proper rate of speed at which work should be done. There are hundreds of operations which are common to most large establishments, yet each concern studies the speed problem for itself, and days of labor are wasted in what should be settled once for all, and recorded in a form which is available to all manufacturers.

391. "What is needed is a hand-book on the speed with which work can be done, similar to the elementary engineering handbooks. And the writer ventures to predict that such a book will before long be forthcoming. Such a book should describe the best method of making, recording, tabulating, and indexing time-observations, since much time and effort are wasted by the adoption of inferior methods."

392. Unfortunately this prediction has not yet been realized. The writer's chief object in inducing Mr. Thompson to undertake a scientific time study of the various building trades and to join him in a publication of this work was to demonstrate on a large scale not only the desirability of accurate time study, but the efficiency and superiority of the method of studying elementary units as outlined above. He trusts that his object may be realized

and that the publication of this book may be followed by similar works on other trades and more particularly on the details of machine-shop practice, in which he is especially interested.

393. As a machine shop has been chosen to illustrate the application of such details of modern management as time study, the planning department, functional foremanship, instruction cards, etc., the description would be far from complete without at least a brief reference to the methods employed in solving the time problem for machine tools.

394. The study of this subject involves the solution of four important problems:

395. First. The power required to cut different kinds of metals with tools of various shapes when using different depths of cut and coarseness of feed, and also the power required to feed the tool under varying conditions.

396. Second. An investigation of the laws governing the cutting of metals with tools, chiefly with the object of determining the effect upon the best cutting speed of each of the following variables:

(a) The quality of tool steel and treatment of tools (*i.e.*, in heating, forging and tempering them).

(b) The shape of tool (*i.e.*, the curve or line of the cutting edge, the lip angle and clearance angle).

(c) The duration of cut or the length of time the tool is required to last before being re-ground.

(d) The quality or hardness of the metal being cut (as to its effect on cutting speed).

(e) The depth of the cut.

(f) The thickness of the feed or shaving.

(g) The effect on cutting speed of using water or other cooling medium on the tool.

397. Third. The best methods of analyzing the driving and feeding power of machine tools and, after considering their limitations as to speeds and feeds, of deciding upon the proper countershaft or other general driving speeds.

398. Fourth. After the study of the first, second and third problems had resulted in the discovery of certain clearly defined laws, which were expressed by mathematical formulæ, the last and most difficult task of all lay in finding a means for solving the entire problem which should be so practical and simple as to enable an ordinary mechanic to answer quickly and accurately

for each machine in the shop the question, "What driving speed, feed and depth of cut will in each particular case do the work in the quickest time?"

399. In 1881, in the machine shop of the Midvale Steel Company, the writer began a systematic study of the laws involved in the first and second problems above referred to by devoting the entire time of a large vertical boring mill to this work with special arrangements for varying the drive so as to obtain any desired speed. The needed uniformity of the metal was obtained by using large locomotive tires of known chemical composition, physical properties and hardness, weighing from 1,500 to 2,000 pounds.

400. For the greater part of the past 22 years these experiments have been carried on, first at Midvale and later in several other shops, under the general direction of the writer, by his friends and assistants, six machines having been at various times especially fitted up for this purpose.

401. The exact determination of these laws and their reduction to formulæ have proved a slow but most interesting problem; but by far the more difficult undertaking has been the development of the methods and finally the appliances (slide rules) for making practical use of these laws after they were discovered.

402. In 1884 the writer succeeded in making a slow solution of this problem with the help of his friend, Mr. Geo. M. Sinclair, by indicating the values of these variables through curves and laying down one set of curves over another. Later my friend, Mr. H. L. Gantt, after devoting about 1½ years exclusively to this work, obtained a much more rapid and simple solution. It was not, however, until 1900, in the works of the Bethlehem Steel Company, that Mr. Carl G. Barth, with the assistance of Mr. Gantt, and a small amount of help from the writer, succeeded in developing a slide rule by means of which the entire problem can be accurately and quickly solved by any mechanic. And Messrs. Gantt and Barth are now engaged in the thoroughly practical work of introducing these slide rules and the methods accompanying them into various machine shops.

403. The difficulty from a mathematical standpoint of obtaining a rapid and accurate solution of this problem will be appreciated when it is remembered that nine independent variables enter into each problem, and that a change in any of these will affect the answer.

404. The writer hopes in the future to read a paper before this Society describing these laws and the method of their application; and he trusts that Mr. Barth may be induced to describe his application of the slide rule to this problem.

405. The instruction card can be put to wide and varied use. It is to the art of management what the drawing is to engineering, and, like the latter, should vary in size and form according to the amount and variety of the information which it is to convey. In some cases it should consist of a pencil memorandum on a small piece of paper which will be sent directly to the man requiring the instructions, while in others it will be in the form of several pages of typewritten matter, properly varnished and mounted, and issued under the check or other record system, so that it can be used time after time. A description of an instruction card of this kind may be useful.

406. After the writer had become convinced of the economy of standard methods and appliances, and the desirability of relieving the men as far as possible from the necessity of doing the planning, while master mechanic at Midvale, he tried to get his assistant to write a complete instruction card for overhauling and cleaning the boilers at regular periods, to be sure that the inspection was complete, and that while the work was thoroughly done, the boilers should be out of use as short a time as possible, and also to have the various elements of this work done on piece work instead of by the day. His assistant, not having undertaken work of this kind before, failed at it, and the writer was forced to do it himself. He did all of the work of chipping, cleaning and overhauling a set of boilers and at the same time made a careful time study of each of the elements of the work. This time study showed that a great part of the time was lost owing to the constrained position of the workman. Thick pads were made to fasten to the elbows, knees and hips; special tools and appliances were made for the various details of the work; a complete list of the tools and implements was entered on the instruction card, each tool being stamped with its own number for identification, and all were issued from the tool room in a tool box so as to keep them together and save time. A separate piece-work price was fixed for each of the elements of the job and a thorough inspection of each part of the work secured as it was completed.

407. The instruction card for this work filled several typewritten pages, and described in detail the order in which the operations

should be done and the exact details of each man's work with the number of each tool required, piece work prices, etc.

408. The whole scheme was much laughed at when it first went into use, but the trouble taken was fully justified, for the work was better done than ever before, and it cost only eleven dollars to completely overhaul a set of 300 H.P. boilers by this method, while the average cost of doing the same work on day work without an instruction card was sixty-two dollars.

409. Regarding the personal relations which should be maintained between employers and their men, the writer quotes as follows from his paper written in 1895. Eight years of additional experience have only served to confirm and strengthen these views; and although the greater part of this time, in his work of shop organization, has been devoted to the difficult and delicate task of inducing workmen to change their ways of doing things he has never been opposed by a strike.

410. "There has never been a strike by men working under this system, although it has been applied at the Midvale Steel Works for the past ten years; and the steel business has proved during this period the most fruitful field for labor organizations and strikes. And this notwithstanding the fact that the Midvale Company has never prevented its men from joining any labor organization. All of the best men in the company saw clearly that the success of a labor organization meant the lowering of their wages in order that the inferior men might earn more, and, of course, could not be persuaded to join.

411. "I attribute a great part of this success in avoiding strikes to the high wages which the best men were able to earn with the differential rates, and to the pleasant feeling fostered by this system; but this is by no means the whole cause. It has for years been the policy of that company to stimulate the personal ambition of every man in their employ by promoting them either in wages or position whenever they deserved it, and the opportunity came.

412. "A careful record has been kept of each man's good points as well as his shortcomings, and one of the principal duties of each foreman was to make this careful study of his men so that substantial justice could be done to each. When men, throughout an establishment are paid varying rates of day-work wages according to their individual worth, some being above and some below the average, it cannot be for the intrest of those receiving high pay to join a union with the cheap men.

413. "No system of management, however good, should be applied in a wooden way. The proper personal relations should always be maintained between the employers and men; and even the prejudices of the workmen should be considered in dealing with them.

414. "The employer who goes through his works with kid gloves on, and is never known to dirty his hands or clothes, and who either talks to his men in a condescending or patronizing way, or else not at all, has no chance whatever of ascertaining their real thoughts or feelings.

415. "Above all, is it desirable that men should be talked to on their own level by those who are over them. Each man should be encouraged to discuss any trouble which he may have, either in the works or outside, with those over him. Men would far rather even be blamed by their bosses, especially if the "tearing out" has a touch of human nature and feeling in it, than to be passed by day after day without a word, and with no more notice than if they were part of the machinery.

416. "The opportunity which each man should have of airing his mind freely, and having it out with his employers, is a safety-valve; and if the superintendents are reasonable men, and listen to and treat with respect what their men have to say, there is absolutely no reason for labor unions and strikes.

417. "It is not the large charities (however generous they may be) that are needed or appreciated by workmen so much as small acts of personal kindness and sympathy, which establish a bond of friendly feeling between them and their employers.

418. "The moral effect of this system on the men is marked. The feeling that substantial justice is being done them renders them on the whole much more manly, straightforward and truthful. They work more cheerfully, and are more obliging to one another and their employers. They are not soured, as under the old system, by brooding over the injustice done them; and their spare minutes are not spent to the same extent in criticising their employers."

419. The writer has a profound respect for the working men of this country. He is proud to say that he has as many firm friends among them as among his other friends who were born in a different class, and he believes that quite as many men of fine character and ability are to be found among the former as in the latter. Being himself a college educated man, and having filled the vari-

ous positions of foreman, master mechanic, chief draftsman, chief engineer, general superintendent, general manager, auditor and head of the sales' department, on the one hand, and on the other hand having been for several years a workman, as apprentice, laborer, machinist, and gang boss, his sympathies are equally divided between the two classes.

420. He is firmly convinced that the best interests of workmen and their employers are the same; so that in his criticism of labor unions he feels that he is advocating the interests of both sides.

421. " He is far from taking the view held by many manufacturers that labor unions are an almost unmitigated detriment to those who join them, as well as to employers and the general public.

422. "The labor unions—particularly the trades unions of England—have rendered a great service, not only to their members, but to the world, in shortening the hours of labor and in modifying the hardships and improving the conditions of wage-workers.

423. " In the writer's judgment the system of treating with labor unions would seem to occupy a middle position among the various methods of adjusting the relations between employers and men.

424. " When employers herd their men together in classes, pay all of each class the same wages, and offer none of them any inducements to work harder or do better than the average, the only remedy for the men lies in combination; and frequently the only possible answer to encroachments on the part of their employers is a strike.

425. " This state of affairs is far from satisfactory to either employers or men, and the writer believes the system of regulating the wages and conditions of employment of whole classes of men by conference and agreement between the leaders of unions and manufacturers to be vastly inferior, both in its moral effect on the men and on the material interests of both parties, to the plan of stimulating each workman's ambition by paying him according to his individual worth, and without limiting him to the rate of work or pay of the average of his class."

426. The amount of work which a man should do in a day, what constitutes proper pay for this work, and the maximum number of hours per day which a man should work together form the most important elements which are discussed between workmen and their employers. The writer has attempted to show that these

matters can be much better determined by the expert time student than by either the union or a board of directors, and he firmly believes that in the future scientific time-study will establish standards which will be accepted as fair by both sides.

427. There is no reason why labor unions should not be so constituted as to be a great help both to employers and men. Unfortunately, as they now exist they are in many, if not most, cases a hindrance to the prosperity of both.

428. The chief reasons for this would seem to be a failure on the part of the workmen to understand the broad principles which affect their best interests as well as those of their employers. (It may be said, however, that employers as a whole are not much better informed nor more interested in this matter than their workmen.)

429. One of the unfortunate features of labor unions as they now exist is that the members look upon the dues which they pay to the union, and the time that they devote to it, as an investment which should bring them an annual return, and they feel that unless they succeed in getting either an increase in wages or shorter hours every year or so, the money which they pay into the union is wasted. The leaders of the unions realize this and, particularly if they are paid for their services, are apt to spend considerable of their time scaring up grievances whether they exist or not. This naturally fosters antagonism instead of friendship between the two sides.

430. There are, of course, marked exceptions to this rule; that of the Brotherhood of Locomotive Engineers being perhaps the most prominent.

431. The most serious of the delusions and fallacies under which workmen, and particularly those in many of the unions, are suffering is that it is for their interest to limit the amount of work which a man should do in a day.

432. There is no question that the greater the daily output of the average individual in a trade the greater will be the average wages earned in the trade, and that in the long run turning out a large amount of work each day will give them higher wages, steadier and more work, instead of throwing them out of work. The worst thing that a labor union can do for its members in the long run is to limit the amount of work which they allow each workman to do in a day. If their employers are in a competitive business, sooner or later those competitors whose workmen do not

limit the output will take the trade away from them, and they will be thrown out of work. And in the meantime the small day's work which they have accustomed themselves to do demoralizes them, and instead of developing as men do when they use their strength and faculties to the utmost, and as men should do from year to year, they grow lazy, spend much of their time pitying themselves, and are less able to compete with other men. Forbidding their members to do more than a given amount of work in a day has been the greatest mistake made by the English trades unions. The whole of that country is suffering more or less from this error now. Their workmen are for this reason receiving lower wages than they might get, and in many cases the men, under the influence of this idea, have grown so slow that they would find it difficult to do a good day's work even if public opinion encouraged them in it.

433. In forcing their members to work slowly they use certain cant phrases which sound most plausible until their real meaning is analyzed. They continually use the expression, "Workmen should not be asked to do more than a fair day's work," which sounds right and just until we come to see how it is applied. The absurdity of its usual application would be apparent if we were to apply it to animals. Suppose a contractor had in his stable a miscellaneous collection of draft animals, including small donkeys, ponies, light horses, carriage horses and fine dray horses, and a law were to be made that no animal in the stable should be allowed to do more than "a fair day's work" for a donkey. The injustice of such a law would be apparent to every one. The trades unions, almost without an exception, admit all of those in the trade to membership—providing they pay their dues. And the difference between the first-class men and the poor ones is quite as great as that between fine dray horses and donkeys (in the case of horses this difference is well known to every one; with men, however, it is not at all generally recognized). When a labor union, under the cloak of the expression "a fair day's work," refuses to allow a first-class man to do any more work than a slow or inferior workman can do, its action is quite as absurd as limiting the work of a fine dray horse to that of a donkey would be.

434. Promotion, high wages, and, in some cases, shorter hours of work are the legitimate ambitions of a workman, but any scheme which curtails the output should be recognized as a device for lowering wages in the long run.

435. Any limit to the *maximum* wages which men are allowed to earn in a trade is equally injurious to their best interests.

436. The "minimum wage" is the least harmful of the rules which are generally adopted by trades unions, though it frequently works an injustice to the better workmen. For example, the writer has been used to having his machinists earn all the way from \$1.50 to seven and eight dollars per day, according to the individual worth of the men. Supposing a rule were made that no machinist should be paid less than \$2.50 per day. It is evident that if an employer were forced to pay \$2.50 per day to men who were only worth \$1.50 or \$1.75, in order to compete he would be obliged to lower the wages of those who in the past were getting more than \$2.50, thus pulling down the better workers in order to raise up the poorer men. Men are not born equal, and any attempt to make them so is contrary to nature's laws and will fail.

437. Some of the labor unions have succeeded in persuading the people in parts of this country that there is something sacred in the cause of union labor and that, in the interest of this cause, the union should receive moral support whether it is right in any particular case or not.

438. Union labor is sacred just so long as its acts are fair and good, and it is damnable just as soon as its acts are bad. Its rights are precisely those of non-union labor, neither greater nor less. The boycott, the use of force or intimidation, and the oppression of non-union workmen by labor unions are damnable; these acts of tyranny are thoroughly un-American and will not be tolerated by the American people.

439. Some method of disciplining the men is unfortunately a necessary element of all systems of management. It is important that a consistent, carefully considered plan should be adopted for this as for all other details of the art. No system of discipline is at all complete which is not sufficiently broad to cover the great variety in the character and disposition of the various men to be found in a shop.

440. There is a large class of men who require really no discipline in the ordinary acceptance of the term; men who are so sensitive, conscientious and desirous of doing just what is right that a suggestion, a few words of explanation, or at most a brotherly admonition is all that they require. In all cases, therefore, one should begin with every new man by talking to him in the most friendly way, and this should be repeated several times over until

it is evident that mild treatment does not produce the desired effect.

441. Certain men are both thick-skinned and coarse-grained, and these individuals are apt to mistake a mild manner and a kindly way of saying things for timidity or weakness. With such men the severity both of words and manner should be gradually increased until either the desired result has been attained or the possibilities of the English language have been exhausted.

442. Up to this point all systems of discipline should be alike. There will be found in all shops, however, a certain number of men with whom talk, either mild or severe, will have little or no effect, unless it produces the conviction that something more tangible and disagreeable will come next. The question is what this something shall be?

443. Discharging the men is, of course, effective as far as that individual is concerned, and this is in all cases the last step; but it is desirable to have several remedies between talking and discharging, more severe than the one and less drastic than the other.

444. Uusually one or more of the following expedients are adopted for this purpose:

First. Lowering the man's wages.

Second. Laying him off for a longer or shorter period of time.

Third. Fining him.

Fourth. Giving him a series of "bad marks," and when these sum up to more than a given number per week or month, applying one of the other of the first three remedies.

445. The general objections to the first and second expedients is that for a large number of offenses they are too severe, so that the disciplinarian hesitates to apply them. The men find this out, and some of them will take advantage of this and keep much of the time close to the limit. In laying a man off, also, the employer is apt to suffer as much in many cases as the man, through having machinery lying idle or work delayed. The fourth remedy is also objectionable because some men will deliberately take close to their maximum of "bad marks."

446. In the writer's experience, the fining system, if justly and properly applied, is more effective and much to be preferred to either of the others. He has applied this system of discipline in various works with uniform success for the past twenty years, and

so far as he knows, none of those who have tried it under his directions have abandoned it.

447. The success of the fining system depends upon two elements: First, the impartiality, good judgment and justice with which it is applied.

Second. Every cent of the fines imposed should in some form be returned to the workmen. If any part of the fines is retained by the company, it is next to impossible to keep the workmen from believing that at least a part of the motive in fining them is to make money out of them; and this thought works so much harm as to more than overbalance the good effects of the system. If, however, all of the fines are in some way promptly returned to the men, they recognize it as purely a system of discipline, and it is so direct, effective and uniformly just that the best men soon appreciate its value and approve of it quite as much as the company.

448. In many cases the writer has first formed a mutual beneficial association among the employees, to which all of the men as well as the company contribute. An accident insurance association is much safer and less liable to be abused than a general sickness or life insurance association; so that, when practicable, an association of this sort should be formed and managed by the men. All of the fines can then be turned over each week to this association and so find their way directly back to the men.

449. Like all other elements, the fining system should not be plunged into head first. It should be worked up to gradually and with judgment, choosing at first only the most flagrant cases for fining, and those offenses which affect the welfare of some of the other workmen. It will not be properly and most effectively applied until small offenses as well as great receive their appropriate fine. The writer has fined men from one cent to as high as sixty dollars per fine. It is most important that the fines should be applied absolutely impartially to all employees, high and low. The writer has invariably fined himself just as he would the men under him for all offenses committed.

450. The fine is best applied in the form of a request to contribute a certain amount to the mutual beneficial association, with the understanding that unless this request is complied with the man will be discharged.

451. In certain cases the fining system may not produce the desired result, so that coupled with it as an additional means of dis-

ciplining the men, should be the first and second expedients of "lowering wages," and "laying the men off for a longer or shorter time."

452. The writer does not at all depreciate the value of the many semi-philanthropic and paternal aids and improvements, such as comfortable lavatories, eating rooms, lecture halls, and free lectures, night schools, kindergartens, baseball and athletic grounds, village improvement societies, and mutual beneficial associations, unless done for advertising purposes. These all tend to improve and elevate the workmen and make life better worth living. Viewed from the managers' standpoint they are valuable aids in making more intelligent and better workmen, and in promoting a kindly feeling among the men for their employers. They are, however, of distinctly secondary importance, and should never be allowed to engross the attention of the superintendent to the detriment of the more important and fundamental elements of management. They should come in all establishments, but they should come only after the great problem of work and wages has been permanently settled to the satisfaction of both parties. The solution of this problem will take more than the entire time of the management in the average case for several years.

453. Mr. Patterson, of the National Cash Register Company, of Dayton, Ohio, has presented to the world a grand object lesson of the combination of many philanthropic schemes with, in many respects, a practical and efficient management. He stands out a pioneer in this work, and an example of a kind-hearted and truly successful man. Yet I feel that the recent strike in his works demonstrates all the more forcibly my contention that the establishment of the semi-philanthropic schemes should follow instead of preceding the solution of the wages question; unless, as is very rarely the case, there are brains, energy and money enough available in a company to establish both elements at the same time.

454. Unfortunately there is no school of management, there is not even a single establishment where a large part of the details of management can be seen, which represent the best of their kinds. The finest developments are for the most part isolated, and in many cases almost buried with the mass of rubbish which surrounds them.

455. Among the many improvements for which the originators will probably never receive the credit which they deserve may be mentioned:

456. The remarkable system for analyzing all of the work upon new machines as the drawings arrived from the drafting-room and of directing the movement and grouping of the various parts as they progressed through the shop, which was developed and used for several years by Mr. Wm. H. Thorne, of Wm. Sellers & Co., of Philadelphia, while the company was under the general management of Mr. J. Sellers Bancroft. Unfortunately the full benefit of this method was never realized owing to the lack of the other functional elements which should have accompanied it.

457. The employment bureau which forms such an important element of the Western Electric Company in Chicago.

458. The complete and effective system for managing the messenger boys introduced by Mr. Almon Emrie while superintendent of the Ingersoll Sargent Drill Company, of Easton, Pa.

459. The Mnemonic system of order numbers invented by Mr. Oberlin Smith and amplified by Mr. Henry R. Towne, of the Yale & Towne Company, of Stamford, Conn.

460. The system of inspection introduced by Mr. Chas. D. Rogers in the works of the American Screw Company, at Providence, R. I.

461. The card system of shop returns invented and introduced as a complete system * by Captain Henry Metcalfe in the government shops of the Frankford Arsenal. The writer appreciates the difficulty of this undertaking as he was at the same time engaged in the slow evolution of a similar system in the Midvale Steel Works, which, however, was the result of a gradual development instead of a complete, well thought out invention as was that of Captain Metcalfe.

462. The many good points in the apprentice system developed by Mr. Vauclain, of the Baldwin Locomotive Works of Philadelphia.

463. The writer is indebted to most of these gentlemen and to many others, but most of all to the Midvale Steel Company for elements of the system which he has described.

464. The rapid and successful application of the general principles involved in any system will depend largely upon the adoption of those details which have been found in actual service to be most useful. There are many such elements which the writer

* Described in "Cost of Manufactures" published by Wiley & Sons.

feels should be described in minute detail. It would, however, be improper to burden the records of this Society with matters of comparatively such small importance. He, therefore, hopes at some future time to publish a supplement discussing these elements.

DISCUSSION.

The Secretary.—I think it would be serviceable if Mr. Taylor would give details as to where the blanks could be obtained to which he refers in his paragraphs 330 and 331 for making available a study of the principles which he has laid down.

Mr. Taylor.—Mr. Sanford E. Thompson at Newton Highlands, Mass., supplies all the apparatus connected with time-study which I have used.

Mr. Henry R. Towne.—Industrial engineering and industrial management are steadily drawing closer together, and rapidly becoming complementary elements in the professional work of a large part of the membership of the Society. The initiative in the introduction of the subject of industrial management to the Meetings and Transactions of the Society was taken in 1889, since when the subject has been under discussion with increasing frequency and, I believe, with increasing interest. It comes legitimately within the scope of the Society's functions, and the tendency to give it increased attention is to be welcomed.

Mr. Taylor's present paper is the most valuable contribution to this subject which has yet been made, and includes so complete a review as to constitute almost a history. It sets forth clearly and fairly the purposes sought, the methods which have been tried, and the results thus far accomplished. It should be appreciated and studied by everyone interested in the subject of industrial management.

The time needed to review it properly is not available to me at present, but I hope to be able to do so at a later date. Meantime I desire to record my appreciation of the praise accorded by Mr. Taylor to the "Gain-Sharing" system described in a paper which I contributed to the *Transactions* in 1889. I concur in his view that the "Gain-Sharing" system is not a complete solution of the problem, but I believe also that, under many conditions, it is the most feasible and effective plan available at present. I wish to call attention to one feature of it which Mr. Taylor does not mention, viz., that in addition to offering a bonus for increased efficiency of labor, it offers an equal reward for economy in the use of materials, machinery and supplies. In many kinds of work these economies are only second in importance to economy in labor.

I endorse strongly the high value placed by Mr. Taylor on the "Contract System" in shop work. Probably the best and most comprehensive plan presently available as a basis of compensation for labor in organized manufacturing is the "Contract System," *plus* piece work as a basis for compensation for the individual workman, *plus* Mr. Taylor's time unit or "pacing" system as a basis for determining piece rates. Such a system is necessarily complex, and therefore entails expense to operate, but the results obtainable under it amply justify the expense involved.

It is to be hoped that Mr. Taylor's paper will bring out others relating to this subject, and that he will incorporate in another contribution to the *Transactions* the supplementary information to which he refers in the closing part of his present paper.

Mr. F. F. Du Brul.—In the discussion of the questions of shop management, raised by Mr. F. W. Taylor, let us not "reckon without our host." To-day we must take into account a very important factor, and one which did not enter very largely into shop questions until recent years: the factor of Unionism.

From a close study of the development of Unionism and its manifestations, I cannot help feeling that anyone attempting to put in such systems as task work, bonus work, piece work, premium work or contract work will meet with more opposition in the future on the part of the Union workmen than has ever been met with in the past. The Machinists' Union, for instance, is socialistic; its journal is socialistic; its policy is socialistic. Moreover, it is stronger now than it ever has been before and in its growing strength, like all other Unions, it is naturally more coercive. How many manufacturers, or other employers of labor, really know how coercive the Unions are? How many employers know that the vast majority of workmen are forced into the Unions against their wishes, this being particularly true of good men. Being in the Union, being subject to its laws and regulations without any hope of freeing themselves from the tyranny of the Walking Delegate and the Strike Boss, such men are unable to do what they would like to do, and what they should be encouraged to do, in the way of bettering their wages and increasing their output.

The policy of the Machinists' Union is restrictive. The socialistic basis of Unionism takes as truth the statement that "labor produces all wealth," and instills into the workman the idea that he will not get his *fair* share of the product until he gets it *all* and naturally leads to more and more systematic "soldiering" in each development of the strength of this idea among the radical element of the Union. Many a man who is not naturally given to "soldiering" is forced into it by his fellow-workmen. I know, for instance, that the president of the Machinists' Union prides himself on the fact that in a number of cases he has succeeded in forcing manufacturers to abolish the "Two Machine" system of operation and putting one man to one machine. We know that a favorite demand of the Machinists' Union is that no handy-man should be permitted to do what the Union considers a machinist's job and that is any work at all on lathe, planer, shaper, milling machine, boring machine, slotting machine, vise or floor, leaving the handy-man simply to lift and carry. We know that in carrying out their ideas of restriction the Unions limit the number of apprentices wherever they are able to a point far beyond any natural and fair degree, making a scarcity of skilled mechanics, which is accentuated with the growth of mechanical industry, forming a "corner" in the labor market of any particular trade, whereby it is hoped to force wages to the utmost.

How many of the members of this Society know that at the last convention of the Machinists' Union, held only a short time ago, it was decided that no work should be allowed in machine shops on any other plan but a "go as you please" day's work plan? All task work, premium work and contract work was to be abolished. Another piece of legislation of that convention was that all honorary retiring cards, which were given to members of the Machinists' Union when put in charge of men, are to be called in, unless the holder of the card earns a salary of $3,500 per year or more. The idea of this is simply to compel foremen to be subject to the Union rather than to their employers, and to give the Union a stronger grip on the shop management.

It is granted that all of these features are illegitimate unionism, but whether they are legitimate or illegitimate, they are a part of the Machinists' Union policy to-day and as such must be reckoned with by the shop manager. He must not only reckon with their policy, but he must reckon with the growing ability and desire to put that policy into force in his own particular establishment. Therefore a question of pressing importance is: "What are you going to do about it?"

Individually the manufacturer cannot oppose the Unions excepting at a tremendous cost, and even if he wins his fight alone he establishes no precedents and he has peace only for a time. His workmen, much as they might desire to continue under conditions of high wages and low labor cost, are coerced or ostracized into "cutting their own throats." The individual manufacturer, no matter how large the establishment, is not much of a protection to the workmen. In fact, if the employer is a stock company whose stock is a matter of public barter on the exchanges, it is exceedingly difficult for such a company to resist the encroachments of the Union.

First, because of the pressure of the stockholders who are looking out for dividends, and cannot see that the maintenance of dividends sometimes requires a strenuous opposition to Union methods, and,

Second, from the directors, who may be making more money on the stock market than they are out of the dividends of their holdings, and therefore will not allow any policy to interfere with the price of the stock on the Exchange. This particularly applies to large companies, and their influence of course reacts tremendously on the smaller concerns.

Some sort of protection against the coercive methods of the Union is absolutely necessary, both for the employer and for the willing employee.

As every disease brings its own remedy, a homœopathic treatment of Unionism has been found to be necessary, applying the principle of "like cures like." To counterbalance the strength gained by organization of the Unions, it is absolutely essential that the employers should also organize. They should organize,

First, for the purpose of defense.

Second, for purposes of educating themselves, their workmen and their foremen, and

Third, from motives of patriotism. In the matter of defense it is self-evident that with the whole power of organized labor concentrated on one individual firm there is much danger to that firm in individual resistance; collective resistance to injustice, however, has never yet failed.

For purposes of education, when employers are organized, discussing on a neutral and fair ground among themselves the problems that confront them, bringing to bear their many minds on the various phases of the problems, they can arrive at a better solution than can any one individual. From the motives of patriotism, unless some efficient check is put on the uneconomic and un-American principles of the Unions, we will not only find our industrial prosperity disappearing, as it has in England, but we will find our individual liberty and the liberties of our workmen undermined by the boycott and the picket.

The great engineers' strike in England demonstrated that only by organization of employers could the evils of Unionism be controlled. The difficulty of the English manufacturers lay in the fact that they organized too late, and unless American manufacturers, and particularly shop managers, awake to a realization of what is going on, put themselves in the way of securing the necessary knowledge as to what Unionism means and what it is doing, and, not only for their own benefit, but for the benefit of this country and its citizens generally, put themselves in the position of effectively resisting the tyrannical and unjust things that are being done at this writing, unless such action is taken by the employers of this country, we will find ourselves confronted with the same evils that to-day confront England.

The only trouble is that each establishment which has not yet been confronted with these phases of the question, feels that it had better not do anything until it is "hit." In this connection, it is well to bear in mind the saying of Napoleon that, "it is human nature not to bother about even the most pressing necessities until some absolutely urgent need arises compelling attention, and then it is just too late." Discounting this feature of human nature was one of Napoleon's characteristics and one of the elements of his success.

It is the writer's earnest desire that the employers of this country will think about this necessity before it is too late, and not allow themselves to be "tied hand and foot" while they are sleeping.

Mr. John T. Hawkins.—The last written discussion of the paper read by the secretary, goes so thoroughly into the subject, and expresses so fully what I intended to say that it leaves little to be added thereto. I desire, however, to endorse those views most emphatically. As he has said or intimated: In all such papers as that under discussion we are indeed "reckoning without our host."

The paper states that it was written with the idea mainly of advocating "high wages and low labor cost." Such a consummation is perfectly possible under proper conditions, and no doubt the paper points out how such desirable industrial advancement might be assisted in some small degree, provided that all such efforts were not offset and nullified a hundred fold by the antagonistic spirit of trade unionism. Under the latter as it exists in this country to-day the primary proposition, as given by the author of the paper, is rendered of so little avail that it seems like a great waste of effort to even consider its particular features in the face of so great an obstacle, without first taking some steps to ameliorate the latter.

The moment an employer attempts to better the conditions of manufacturing—to cheapen them however little by refinement of his processes, he is met by the infinitely greater obstacles placed in his way by the labor unions; and there is little use in their straining at their own gnats of improvement so long as they are obliged to swallow the labor union camels.

The spirit of these unions is everywhere antagonistic to the cheapening of products or the methods of their production, on the principle that the less every man does the more will there be for the rest to do. They put every obstacle possible in the way of employers availing themselves of labor-saving machinery. It is the same spirit that destroyed cotton gins, looms and nail machines in older times. They have never yet been brought to see that if an employer cheapens the cost of his product by improvement in methods and machinery he thus becomes so much the better able to pay high wages; or that the converse obtains.

I think, therefore, that this paper, while most admirable in conception, is, as my predecessor above quoted has said, counting without its host. If this Society will formulate, mathematically or otherwise, some plan which will induce every man who enters a shop to work to do the best that is in him for the wages he has agreed to receive—which was generally the fashion when I was a young man—instead of doing the least possible, as is now the prevailing style, the object set forth by this paper would be more than possible; it would bring about that object a thousand fold beyond anything in that direction to be accomplished by any such means as is advocated in the paper under the antagonism of unionism. In fact it is the one and only path to the lowering of labor cost while increasing wages, and it is to be hoped that some of these days—after perhaps a good many more years of costly experience—the labor unions or their individual members will be brought to see it. Until they do, and we continue to swallow their industrial camels, we might as well let our own gnats alone.

Mr. H. Emerson.—For several years there has been industrial activity in the United States. We hope it may last, but to make it last we should realize the causes of this prosperity and aim to convert spasmodic accident into permanent, rational advantage.

America, north of the tropics, thus including Canada, is a region of great natural resources, with superior producing and transportation equipment, mainly peopled by active, intelligent inhabitants. This is, however, not enough. There was no prosperity in this vast region from 1893 to the latter half of 1897, and then it was solely owing to a series of accidents that a great flood of abundance came, still running full. These accidents were the discovery of new gold fields of great richness, with a sudden and general increase in gold output; a famine abroad resulting in dollar and almost two dollar wheat for a whole season of exceptionally bountiful harvests at home; a foreign war with sudden expenditures aggregating $1,000,000,000.

The gold yield eased the money market of the world, our exports brought in over $1,000,000,000, our home war expenditures put into rapid circulation $1,000,000,000 more, and as a consequence vast works of rebuilding were undertaken. It is not too much to say that in the 17 years from 1893 to 1910 all the railways in their road beds, track, bridges, terminals, rolling stock and motive equipment will be rebuilt; that the trolley systems will become equal to the steam railroads in mileage; that the whole ocean fleet is to be rebuilt, that the business and best residential portions of all our cities are to be rebuilt, and finally but not least, that every machine shop, every machine tool is to be re-equipped.

When all this construction is done, what then? Shall we or shall we not be better prepared than our industrial rivals to capture the world's trade? If we then do not have the relief and refuge of foreign markets, from which we must displace rivals already in possession, unless we can substitute *production* and *operation* for construction, the more we have done, the greater will be the horrible depression.

To conquer and hold foreign markets we must produce and distribute more cheaply and manage with greater skill and intelligence than any other region in the world, and one of the tasks of good management is to diminish dissensions.

It is not enough to have great fields, rich mines, fine railroads and great industrial plants. Unless the man who works with his brains can harmonize the relations between those who work with their hands and those who work with their money, the efforts which should be directed and concentrated towards holding our own in the industrial world will be misdirected and frittered away in internal friction.

The minds of many are alive with apprehension as to the future. On all sides we hear the warning that the relations between employers and employés constitute the one great danger. It is because I believe that the continuance of natural prosperity can only be attained by underbidding the rest of the world, and because I believe that we can only underbid by surpassing the rest of the world, not only in natural resources but in harmony between employé and employer, in extensive organization, in eliminating from our national life waste methods, waste processes, waste time, I regard the paper presented at this meeting by Mr. Taylor as the most important contribution ever presented to the Society, and one of the most important papers ever published in the United States. Mr. Day's paper on "Machine Shop Organization," Mr. Gantt's on a method of following work through a shop are fitting introduction and sequel to Mr. Taylor's great paper.

Mr. Taylor's achievement is that he is the first one to use perfected scientific methods, one of them a microscopic study of Time Units to get at the elemental cost of all production. He shows how the combination of methods and equipment designed by the brain worker, paid for by the capitalist and operated by the skilled worker can reduce costs of output to one-third of what they usually are.

Mr. Taylor does not stop here. The brain worker and the capitalist have long been working in harmony, but the third partner is an antagonist. Mr. Taylor shows the method by which, not as a concession or dole, but by a self-operating plan, the worker must be paid increasingly more if output is to be cheapened.

In his essay Mr. Taylor treats only of the application of his plans to the machine shop. They are, however, of far greater reach. A somewhat careful study based on unusual opportunities of observation has convinced me that the rational efficiency of the male population of the United States of militia age does not exceed five per cent. as compared to the nintey-five per cent. of the ideal machine shop planned and equipped let us say by Messrs. Dodge and Day, organized and directed by Mr. Taylor, and the work followed through under the methods of Mr. Gantt.

The greatest latent wealth of a country does not lie in its natural resources, not in its fertile fields or numerous railroads, not in its forests and mines. Switzerland is rugged, barren, cut off from the sea, without coal or iron, yet because its inhabitants are thrifty, frugal, intelligent, it has become one of the greatest manufacturing countries in the world. New England is in North America what Switzerland is to Europe. Solely by intelligent organization, not by natural resources, Prussia jumped to the front as a military power. Germany has jumped to the foremost rank in marine construction.

Were all our inhabitants as frugal and thrifty as the Swiss or Japanese, as intelligently alert and energetic as the New Englanders, were our industries organized as is German shipbuilding, were Mr. Taylor's methods generally applied, no country in the world would compete with North America.

There should be no fear by the worker that his store of increased remuneration can be curtailed. If the United States can produce and deliver cheaper than the balance of the world, every worker in America will find a reasonable opportunity to keep busy. His increase of pay and shortening of hours must be his share of the economies possible below the danger point of competition, and as the possible economies between perfect adjustment and present anarchy are close to ninety per cent. of the final cost to consumer, as it is much easier to attract twice as much capital by a slightly increased rate and to double the number of highly specialized brain workers than suddenly to double the number of workers, each working member under the rational Taylor system will have it absolutely in his hands to exact his share of the economy. If there is a product now costing 1,000 units to be produced in a shop planned and equipped by Messrs. Dodge and Day, organized and directed by Mr. Taylor, work followed through by Mr. Gantt, so as to reduce cost to 300 units, even if the specially skilled, trained and willing workman required to run such a shop were paid 100 per cent. above the average, as Mr. Taylor suggests, if by organizing the relations between the shop and the community the cost could be still further reduced from 300 to 100 units, as from my own experience and results in organizing work I know it often can be, then by the operation of natural laws the skilled American worker must of necessity receive more, not less than the percentage allowed by Mr. Taylor.

Mr. Taylor has done more than point the way. It is henceforth the organizer's, the planner's own fault if labor's discontent cannot be successfully allayed and harmony be secured where now there is antagonism.

A beautiful lesson can be learned from the way the bees have been induced to increase the production of honey. The bees are perfected socialists, and no one can induce them to change either their habits, laws or methods, yet by adjusting equipment and implements to their rules of life, the net result is that the bees have a pleasanter, safer time and more abundant provision against want, while the man who has co-operated with the bees obtains three times as much honey as his European peasant rival and a hundred times as much honey as the savage who despoils without either directing or co-operating.

In the past, management, often skilled, often wise and selfish has evolved many plans to force from unwilling men an increase of effort without corresponding increase of reward. The workers have retaliated by organizations which as unreasonably expect to increase wages and shorten hours without correspondingly lessening cost. Such wasteful methods should be left to Europe, and organizing and harmonizing work should be placed in the control of those who, with experience of their own and results to show, are almost able to guarantee harmony of relations and very greatly reduced costs.

Mr. F. A. Halsey.—I do not consider that Mr. Taylor is justified in calling the Premium Plan the Towne-Halsey plan. Of course it is a difficult matter to draw hard and fast lines in these matters, but I cannot regard Mr. Towne's plan as an anticipation of my own. It is much more closely allied to profit sharing, from which it differs chiefly in limiting the gains which are divided among the workmen to those under their control. It is thus a strictly economic and not an eleemosynary plan, which latter the profit sharing plan is. In its method of administration it is precisely the same as the profit sharing plan, with which again it agrees in treating the men in a body and not as individuals.

Mr. Taylor characterizes the Premium Plan as a drifting system and as being based upon deceit, by which I take it he means that records established by the workmen are used as the basis of the system. In my paper, "The Premium Plan of Paying for Labor," which appears in Vol. XII of the *Transactions*, the following will be found upon page 764:

"On contract work undertaken for the first time, the method is the same except that the premium is based on the *estimated* time for the execution of the work."

Now, as I look at it, what Mr. Taylor has done in connection with his time study methods has been to determine the estimated time with greater accuracy. The fact is that this basing of the Premium Plan upon the estimated time is a very common thing in Great Britain. It is a curious fact that while the plan has, in this country, been applied chiefly to repetition work, it has in Great Britain, been applied chiefly to work of the opposite character. This is probably due to the fact that it was first adopted in Great Britain by David Rowan & Co., of Glasgow, who are builders of marine engines, and the spread of the system has been to shops which are essentially of the same general character. In nearly all of the numerous papers upon the system which have been presented to British engineering societies, a great deal of attention has been paid to the rate fixing department, which is considered an essential feature of the system, as indeed it is with work of the character there done. This term "rate fixing department" was the first one used by Mr. Taylor for what he now calls the "time study" department and the use of the term in Great Britain no doubt follows Mr. Taylor's use of it here.

No doubt this rate fixing is not done by the minute methods of analysis which Mr. Taylor uses, but the point is that through it the Premium Plan is used on work which has not been made before, and hence it seems to me that this statement of Mr. Taylor that the system is a drifting system and based on deceit is unfounded. The essential feature of the system relates to the method of payment and not to the method of setting the rates.

The leading difference beween Mr. Taylor's plan and my own is that he tells the workman by means of his instruction cards how to produce the expected results, whereas my plan depends upon the initiative of the workman. I have no doubt that there is a large field of work to which Mr. Taylor's plan is applicable, and in which it will produce better results than my own, but I am just as well satisfied that there is a much larger field in which we cannot afford the expense attending the organization which Mr. Taylor contemplates and in which better results will be obtained in the end by depending upon the initiative of the workman. The conditions which Mr. Taylor found at Bethlehem and at Midvale are ideal for his system, but I do not believe that they furnish criteria for the general usefulness of the system.

It should be noted that Mr. Taylor's plan not only determines the maximum output, but deliberately tells the workman how to produce that output—every possible means being provided for inducing and even compelling him to adopt the combination of feed, speed, etc., which has been determined to be most suitable. Now, when the workman has done this, why should a bonus be paid him for doing it? He has simply followed orders and produced expected results, and I am unable to see the justification for any additional pay for doing that. My plan pays the premium as a reward for the workman's use of his wits and his intelligence. Mr. Taylor's plan takes the exercise of that intelligence entirely away from the workman and lodges it in someone else who is paid especially for the exercise of those functions, and it seems to me that in taking away the very thing for which the premiums are paid, it has destroyed the economic soundness of the premiums. Of course this remark does not apply to manual labor, in which the increased output is obtained only by increased exertion by the workman; but when it comes to the operation of machines without additional effort of any kind on the part of the workman, the justification for increased pay is destroyed.

Mr. F. W. Taylor.—After hearing Mr. Halsey's criticism it seems to me that he is under a misapprehension as to the true underlying principles of the Towne-Halsey plan and my system.

There is no doubt that there is more or less confusion in the minds of many of those who have read about the two systems, and this extends also to those who are actually using and working under them. This is practically true in England, where in some cases my system is actually being used under the name of the "Premium Plan." It would therefore seem desirable to indicate more clearly the essential difference between the two.

The one element which the Towne-Halsey plan and my system of management have in common is that both recognize the all important fact that workmen cannot be induced to work extra hard without receiving extra pay. Under both systems the men who succeed are daily and automatically as it were paid an extra premium. The payment of this daily premium forms such a characteristic feature in both systems and so radically differentiates these systems from those which were in use before, that people are apt to look upon this one element as the essence of both systems and so fail to recognize the more important, underlying principles upon which the success of each of them is based.

In their essence, with the one exception of the payment of a daily premium, the systems stand at the two opposite extremes in the field of management; and it is owing to the distinctly radical, though opposite, positions taken by them that each one owes its success; and it seems to me a matter of importance that this should be understood. In any executive work which involves the co-operation of two different men or parties, where both parties have anything like equal power or voice in its direction, there is almost sure to be a certain amount of bickering, quarreling and vacillation and the success of the enterprise suffers accordingly. If, however, either one of the parties has the entire direction, the enterprise will progress consistently and probably harmoniously, even although the wrong one of the two parties may be in control.

Broadly speaking, in the field of management there are two parties—the superintendents, etc., on one side and the men on the other, and the main questions at issue are the speed and accuracy with which the work shall be done. Up to the time that my system was introduced in the Midvale Steel Works, it can be fairly said that under the old systems of management the men and the management had about equal weight in deciding how fast the work should be done Shop records showing the quickest time in which each job had been done and more or less shrewd guessing being the means on which the management depended for bargaining with and coercing the men; and deliberate soldiering for the purpose of misinforming the management being the weapon used by the men in self-defence. Under the old system the incentive was entirely lacking which is needed to induce men to co-operate heartily with the management in increasing the speed with which work is turned out. It is chiefly due, under the old systems, to this divided control of the speed with which the work shall be done that such an amount of bickering, quarreling and often hard feeling exists between the two sides.

The essence of my system lies in the fact that the control of the speed problem rests entirely with the management, and on the other hand, the true strength of the Towne-Halsey plan rests upon the fact that under it the question of speed is settled entirely by the men without interference on the part of the management. Thus in both cases, though from diametrically opposite causes, there is undivided control, and this is the chief element needed for harmony.

So far as I know, I was the first to introduce a system of management containing the following elements:

1. A careful study of the time required to do the work.

2. Detailing instructions to the men, telling them how they are to do their work.

3. The thorough standardization of all details which affect the speed of the work.

4. The payment of a premium for success accompanied by a corresponding loss in case of failure.

This system was introduced in the Midvale Steel Works of Philadelphia in 1884. In 1889 Mr. Towne read his paper on "Gains Sharing" before this Society, and in 1891, seven years after my system had been in use on an extensive scale, Mr. Halsey wrote his paper on the "Premium Plan."

Mr. Halsey has objected to having his scheme called a "drifting" system. I have used the word "drifting" without the slightest intention of slurring it or in the least detracting from its true merit. It appears to me, however, that "drifting" very accurately describes it, for the reason that the management, having turned over the entire control of the speed problem to the men, the latter being influenced by their prejudices and whims, drift sometimes in one direction and sometimes in another; but on the whole, sooner or later, under the stimulus of the premium, move toward a higher rate of speed. This drifting, accompanied as it is by the irregularity and uncertainty both as to the final result which will be attained and as to how long it will take to reach this end, is in marked contrast to the distinct goal which is always kept in plain sight of both parties under my system, and the clear-cut directions which leave no doubt as to the means which are to be employed nor the time in which the work must be done; and these elements constitute the fundamental difference between the two systems. Mr. Halsey, in objecting to the use of the word "drifting" as describing his system, has referred to the use of his system in England in connection with a "rate fixing" or planning department, and quotes as follows from his paper to show that he contemplated control of the speed of the work by the management:

"On contract work undertaken for the first time the method is the same except that the premium is based on the estimated time for the execution of the work."

In making this claim Mr. Halsey appears to have entirely lost sight of the real essence of the two plans. It is my system which is in use in England, not his; and in the above quotation he describes not his system but mine, in which the men are paid a premium for carrying out the directions given them by the management. He has forgotten that under my system the men were paid a premium for doing the work in the time estimated by the management seven years before he wrote his paper.

In questioning why any premium is necessary under my system in the latter part of his remarks, Mr. Halsey appears to have entirely lost sight of the necessity for the one element which the two systems have in common, namely, the payment of a premium for extra hard work. I think that I have called attention so carefully in the paper to the fact that men will not do extra hard work for ordinary pay that no further reference to this fact is required. It is needless to say that machines do not run themselves, but are run by men, and the larger the amount of work turned out by the machine the greater will be the work and attention demanded from the workman.

There is ample room for the use of the Towne-Halsey plan as well as for mine, but the line of demarkation between the two is not that drawn by Mr. Halsey. My system is not only applicable to large works such as the Midvale Steel Company and the Bethlehem Steel Company, as implied by Mr. Halsey. It is applicable to and in successful use in works of all kinds, large and small, complicated and simple, and can be used for all kinds of labor. It is capable, in my judgment, in all cases, of producing both quicker and much more certain, larger and more satisfactory results to both sides than the Towne-Halsey plan. I clearly recognize the fact, however, that there are many employers who will not give the time nor take the trouble to introduce my system; and to such men the Towne-Halsey plan is to be recommended as better than any of the old systems in common use.

Mr. Oberlin Smith.—If the argument of one of the last speakers was carried out, it would resemble the case of the Irishman who went to a store to buy a cook stove, the storekeeper assuring him it would save half his coal bill, whereupon he said, "Sure I'll take two stoves and save it all!"

Now a word about unions. I think that if we are going to be pessimistic, and to expect that all these efforts to improve our methods and cheapen our products are going to be foiled by unions we are mistaken. There are several elements which will gradually rid us of these troubles. One is that the men composing the unions, as they become better educated and affiliate more with people like us, will become more sensible. I think one of the greatest works which this Society could do would be to foment some system throughout the country for introducing a new political economy into our public schools. If certain economic treatises especially devoted to the labor problem could be taught freely in our public schools we would raise up a generation of boys who would know that the greater production there is in this world, with a given effort, the richer they would all be in the long run. The workingmen do not know enough now, but they are all the time learning. And then we may get something like the New Zealand system, where labor unions are desired by employers and by employed alike—and where manufacturer's unions are equally recognized and desired by all parties. That is, both unions desire each other, and all disputes are passed upon by commissioners appointed by both. If they fail, appeal is made to a higher commission under the control of the Government, and partially composed of one or more judges of the Supreme Court. This system is said to be working exceedingly well. It is to be hoped that we shall gradually come towards something like that in this country. Another element that already has a beginning consists of such associations as the American Metal Trades Association which, although apparently formed to combat the unions, is really affiliating to some extent with them—making the employers and the workingmen better acquainted all the time. When we get so that officers of such associations can take a glass of beer with the workingman's representatives and talk the matter out, we may get some of these troubles settled, and all have a pretty good time.

I want to congratulate the Society and the writers of these three papers upon the splendid work they have given us, and especially Mr. Taylor, because his paper is more comprehensive than the others. One fine point about it is that it is not his only. He has taken in all that is good that he could get from anywhere, and I believe the Society is doing a good work in disseminating such facts and records as are contained in papers of this sort.

Mr. Ayres.—I want to say that I have taken charge of an old plant. The plant was unionized. I tried to put in this system and for four months was practically unable to do so: that is, the bonus system. Finally one man consented to take it. He was planing guides. He succeeded in making his bonus for two days then stopped. I paid no attention to it for as much as a week, noticing it, however, every day. I finally went to the man and said: "Wilson, how does it happen that you have given up your bonus? That was worth forty cents a day to you?" He said, "Did you notice the guides the other day? They had written on them, 'He is driving us out of a job'; 'Metal pushed off, not cut,' and a few other inscriptions of a similar character. Those remarks had been put on by some of his fellow workingmen. He, however, took up the bonus again, and at the end of two weeks he said he had a cousin working in the shop who would like to take up the bonus business too. I was very glad, of course, and I fixed an instruction card at once, so that he could begin it that day. I do not want you to compare the times of doing the work, which perhaps I might give you, with what could be done in some other shops where you have the best of machinery, but I will simply tell you what was done, and what is being done. We were boring some brasses, and I allowed a man forty minutes to do it in. His day rate was 22½ cents an hour. He did those brasses in thirty-seven and one-half minutes instead of taking forty minutes. With the bonus which I allowed him, the wages which that man earned were 27.6 cents per hour instead of 22½ cents. The cost per piece to me was 17¼ cents, where before it was done on the bonus work it was 28 cents. Showing a decrease in cost of about 10¾ cents per piece to me and an increase to him of practically fifty cents per day. The planing of frames was another instance of which I have the figures here. A man running a planer was getting 20 cents per hour. With his bonus he made 24.1 cents per hour, decreasing my cost at the same time, and not only doing that but at the same time increasing the output. So that we are getting a larger output with the same capital tied up in the plant. I could give you other intances of the same kind. Paneling main rods, a man on the milling machine was getting 22 cents an hour, and he made 32.8 cents per hour, and at the same time decreased the cost of the output 24 per cent. I have no trouble in getting men to take bonus work now.

Mr. Gantt.—I just introduced Mr. Ayres as he is a new member and rather bashful. Now I would like to say a word or two on my own hook. What Mr. Ayres said is about a locomotive works, not a steel works; but the principles applied there are the principles said to be only applicable to a steel works. I do not care to enlarge upon that, because those who know what the locomotive is know that the work done in the locomotive shop is about as general as it is anywhere else.

Mr. John Balch Blood.—All careful considered action comes through the following processes:

Perception of conditions.
Collection of data.
Collation of facts.
Development of criteria.
Application to action.

At present a larger part of the wage question is determined without any adequate basis of information upon which to act, and the systematic method of obtaining information which is used in every branch of engineering and on all important questions is apparently ignored in this question, which question is one of the fundamental social questions. The bringing forth of the importance of accurate information on this subject by Mr. Taylor cannot be too strongly valued, as it alone would largely aid in this subject irrespective of anything else. In my experience I have found that any method of determining wages where personality enters is sure to breed suspicion and discontent. It would seem, therefore, that some other basis than time should serve as a basis of wage calculation.

I believe that the basis of calculation should be other than time, and in working out this problem myself I have made use of what I call "work units," which units would present two factors—time and intensity, ability or skill. In determining such work units, personal factor of soldiering or incorrect timing would not appear, and the relative value in two different jobs could be demonstrated to the satisfaction of laborer and employer.

I believe that all form of labor from purely manual labor to the highest skilled labor should appear in the same category as work units, and that the wage should be so much per work unit with a given rate and with an increasing price per unit for an increased rate. For instance, the following might serve for a schedule.

Units per day.	Rate per unit.	Daily wage.
1.00	$1.00	$1.00
1.50	1.10	1.65
2.00	1.20	2.40
2.50	1.35	3.38
3.00	1.50	4.50
3.50	1.70	5.95
4.00	1.90	7.60

It is quite necessary that the price per unit be increased with the increased rate of units per day. With this system a man working on a given piece of work might work at different rates. At all times the incentive to increase rate would be present, as the increased pay per unit would take effect on the whole work if the rate per day was increased. This could be still further emphasized by placing the work in classes and allowing an extra premium for an increase from one class to another, on condition that a forfeit be recognized if the speed of the higher class was not maintained.

Lack of knowledge breeds suspicion and antagonism. A thorough system of making rates which is demonstrable and which is independent of personality will bring mutual helpfulness and increase the annual output of work.

Mr. John T. Hawkins.—I want to give you a couple of instances illustrating the spirit of trades unionism towards the idea of reducing the cost of products.

In a machine shop which had been forced to become an exclusively union shop in order to avoid a supposedly disastrous boycott which had been threatened, there was a little labor-saving device with which you are all familiar, namely a power hack-saw.

I need not tell you that this little machine requires almost no attention: when cutting off say 1½ inch round rods not more than a half minute in every hour. When the shop was a *free one* it had been the practice to require someone otherwise generally engaged to reset the tool when a piece dropped off. As soon as it became a union shop, however, the so-called "shop steward," who thenceforward practically ran the shop, insisted that a boy be kept sitting by this machine all day, while actually occupied less than one-twelfth of his time. This is the way that labor-saving device was permitted to save labor; and there is not the slightest doubt that had the proprietor refused to comply he would have had a strike on his hands.

Another typical case is this: I had occasion to solicit an estimate for a large lot of a new article of glass from a glass works in New Bedford, Mass. The manager informed me that I would have to furnish a mold at my own expense, to which I agreed; but before going to that expense desired to know the price at which he would furnish the goods. He informed me that nothing could be done until the mold was produced, upon which he would submit the same to the glass makers' union, and as soon as their walking delegate or business manager, or whatever this important individual was then called, decided how many of the articles he would allow a man to make for a day's work, the proprietor would give me the figures desired.

Mr. H. M. Lane.—I would like to say just a word upon the subject. For several years I have been watching the machine shops of the country, gathering material for our Shop Practice Course, in Scranton. I have been very much interested in a series of circumstances occurring in one of the largest shops in this country. I have seen it pass under three managements, and it has been very instructive to me as to what could be done in a strongly organized union shop. First, the manager tried to drive everything through the shop without having a good system of keeping track of the work. The result of his effort was that the shop was always in a congested condition, with work and castings piled up in every direction. Castings were lost and never found and all sorts of trouble were experienced.

The next manager that came in got hold of the foreman and superintendent and started a series of blanks in operation, which were evidently working nicely when they changed superintendents again. Up to this time the management made practically no change in equipment, but the introduction of the blanks had to a large extent cleared up the floor. The new superintendent got the idea that he was kind of a bulldog and his idea was to chase everything, hence he dropped a large portion of the blank system and tried to chase the men and the work until he chased himself out.

The next superintendent who took charge dropped between the two extremes and he has accomplished two things. First, he adopted a system of blanks which enabled him to prevent the loss of castings and tell whether the work was getting along right or not, but the point which interested me most was the way he has gotten around the men in regard to getting work out. For instance, in the foundry where they were making a certain piece of work in a loam mould, the men limiting the output, he simply turned around and made it in dry sand. By changing his method in this case and in others, and taking the work out of the hands of one class of moulders and putting it into the hands of another he was able to circumvent their idea as to how fast a particular piece of work should be done. He first made an estimate of the time the work should take, and then by changing the method and making the necessary rigging he got the work done according to his estimate. In the machine shop the new high speed tool steel and the use of new machines has enabled him to make similar changes and a corresponding saving of time.

Mr. Henshaw.—As pointed out by one of the last speakers, the subject we have under discussion is of enormous importance—probably the most important industrial engineering question that has ever come before this Society. We have been familiar for years with the splendid work of Mr. Taylor and others, but, like a great many good things, when we come away from these meetings we are apt to say, " Oh, yes, it can be done in that shop, but my conditions are a little different, and I don't think it would pay me." Then, again, we have the bugbear of Trades Unions in the background. Now the suggestion that I would like to make is that this Society form a standing committee on the subject of shop management, and consider all the data which have been brought up, and, if it takes them twenty years, get out of it if possible a system so perfect that it can be universally applied. It may be then that by the application of such a system in every shop the Trades Union question will be settled. It seems to me that such a result is possible.

Mr. Wm. Kent.—Apropos of what the last speaker has said, we all remember that about the year 1775 some people down in Boston were talking about a tax on tea, and some of them said they would have to submit to it, otherwise their warehouses and docks would be shut up and their business destroyed. Now the descendants of those people say if we attempt to oppose the unions the unions will shut us up and drive us out of business. Then, too, I think we all remember that there was another set of men back in 1775 who went and threw that tea in Boston

Bay and started the Revolutionary War. I hope there is some of that kind of blood left in New England yet.

Mr. Taylor.—Mr. DeBrule and Mr. Hawkins have called attention to the most interesting and difficult problem connected with management, namely, how to persuade union men to do a full day's work if the union does not wish them to do it. I am glad of the opportunity of saying what I think on the matter, and of explaining somewhat in detail just how I should expect, in fact, how I have time after time induced union men to do a large day's work, quite as large as other men do.

In dealing with union men certain general principles should never be lost sight of. These principles are the proper ones to apply to all men, but in dealing with union men their application becomes all the more imperative.

1. One should be sure, beyond the smallest doubt, that what is demanded of the men is entirely just and can surely be accomplished. This certainty can only be reached by a minute and thorough time study.

2. Exact and detailed directions should be given to the workman telling him, not in a general way but specifying in every small particular, just what he is to do and how he is to do it.

3. It is of the utmost importance in starting to make a change that the energies of the management should be centered upon one single workman, and that no further attempt at improvement should be made until entire success has been secured in this case.

Judgment should be used in selecting for a start work of such a character that the most clearcut and definite directions can be given regarding it, so that failure to carry out these directions will constitute direct disobedience of a simple, straightforward order.

4. In case the workman fails to carry out the order the management should be prepared to demonstrate that the work called for can be done by having some one connected with the management actually do it in the time called for.

The mistake which is usually made in dealing with union men, and which I have no doubt Mr. Hawkins made, lies in giving an order which affects a number of workmen at the same time and in laying stress upon the increase in the output which is demanded instead of emphasizing one by one the details which the workman is to carry out in order to attain the desired result. In the first case a clear issue is raised: say that the man must turn out fifty per cent. more pieces than he has in the past, and therefore it will be assumed by most people that he must work fifty per cent. harder; and in this issue the union is more than likely to have the sympathy of the general public, and they can logically take it up and fight upon it. If, however, the workman is given a series of plain, simple and reasonable orders, and is offered a premium for carrying them out, the union will have a much more difficult task in defending the man who disobeys them. To illustrate: If we take the case of a complicated piece of machine work which is being done on a lathe or other machine tool, and the workman is called upon (under the old type of management) to increase his output by twenty-five or fifty per cent., there is opened a field of argument in which the assertion of the man, backed by the union, that the task is impossible or too hard will have quite as much weight as that of the management. If, however, the management begins by analyzing in detail just how each section of the work should be done and then writes out complete instructions specifying the tools to be used in succession, the cone step on which the driving belt is to run, the depth of cut and the feed to be used, the exact manner in which the work is to be set in the machine, etc., and if before starting to make any change they have trained in as functional foremen several men who are particularly expert and well informed in their specialties, as, for instance, a speed boss, gang boss and inspector; if you then place for example a speed boss alongside of that workman, with an instruction card clearly written out, stating what both the speed boss and the man whom he is instructing are to do, and that card says you are to use such and such a tool, put your driving belt on this cone, and use this feed on your machine, and if you do so you will get out the work in such and such a time, I can hardly conceive of a case in which a union could prevent the boss from ordering the man to put his driving belt just where he said and using just the feed that he said; and in doing that the workman can hardly fail to get the work out on time. No union would dare to say to the management of a works, you shall not run the machine with the belt on this or that cone step. They do not come down specifically in that way; they say, "You shall not work so fast," but they do not say, "You shall not use such and such a tool, or run with such a feed or at such a speed." However much they would like to do it, they do not dare to interfere specifically in this way.

Now, when your single man, under the supervision of a speed boss, gang boss, etc., runs day after day at the given speed and feed and gets work out in the time that the instruction card calls for, and when a premium is kept for him in the office for having done the work in the required time, you begin to have a moral suasion on that workman which is very powerful. At first he won't take the premium if it is contrary to the laws of his union, but as time goes on and it piles up and amounts to a big item, he will be apt to step into the office and ask for his premium, and before long your man will be a thorough convert to the new system. Now, after one man has been persuaded, by means of the four functional foremen, etc., that he will earn more money under the new system than under the laws of the union, you can then take the next man, and so convert one after another right through your shop, and as time goes on public opinion will swing around more and more rapidly your way.

I have a profound respect for the workmen of the United States; they are in the main sensible men—not all of them, of course, but they are just as sensible as we are. There are some fools among them; so there are among us. They are in many respects misguided men, and they require a great deal of information that they have not got. So do we.

I have quite as great a respect for the workmen of this country as for any other class of men. They are a sensible body of men, and all that they need to make them do what is right is a series of proper object lessons. When they are convinced that a system is offered them which will yield them larger returns than the union can offer they will promptly drop the union. The necessary object lessons can best be given by centering the efforts of the management upon one spot. The mistake that ninety-nine men out of a hundred make—and I fancy that Mr. Hawkins' friends in Massachusetts have done this—is that they have attempted to influence a large body of men at once instead of taking one man at a time.

I think that Mr. Hawkins has also overlooked another important factor, and that is the question of time. If Mr. Hawkins expects large results in six months or a year in a very large works he is looking for the impossible. If he expects to convert union men to a higher rate of production, coupled with high wages, in six months or a year, he is expecting next to an impossibility. But if he is patient enough to wait for two or three years, he can go among almost any set of workmen in this country and not find the trouble which he did in Massachusetts.

Mr. Hawkins.—I have waited six years now.

Mr. Taylor.—Have you tried the incisive plan of centering on one man, instead of going at the whole shooting-match at once? I think failure is due to a lack of patient persistence on the part of the employers and then to a lack of centering right on to a single man. No workman can long resist the help and persuasion of five foremen over him. He will either do the work as he is told to or leave.

Mr. Gus. C. Henning.—We have heard much about this interesting subject and have been deeply interested, and we have heard so much as to how to make money and to get along with men that I think we might very well now pass a vote of thanks to Mr. Day, Mr. Gantt and Mr. Taylor. Gentlemen, I hope you will vote with me and give a hearty vote to these three gentlemen for the presentation of these admirable papers.

The motion was seconded and carried unanimously.

No. 1004.*

TOPICAL DISCUSSIONS AND NOTES OF EXPERIENCE.

No. 155.

Has anyone had experience in manufacturing small spiral pinions in a milling machine?

Mr. E. H. Neff.—In answer to the above question the writer would present the attachment shown in the adjacent cuts. This attachment was invented by Mr. W. G. Burnham, and designed by the writer to meet the requirements of a company engaged in the manufacture of cream separators. In their apparatus, on the vertical spindle which carries the bowl into which the milk is poured, is a spiral pinion, or as it is sometimes designated, a "worm." These have a low number of teeth, 6, 7, or 8, and the diameter will run from about $\frac{1}{2}$ inch to $\frac{7}{8}$ of an inch. The length of cut varies from $1\frac{1}{4}$ inches up—sometimes as long as 5 inches. The angle of thread is from 45 degrees to 51 degrees, making 20-pitch to 32-pitch cutters, about equal to the normal pitch of the smaller sizes. In the train of gearing this pinion is the driven member, being driven by a worm-wheel, which is in turn driven by a train of spur gears, thus attaining for the worm-shaft of the separator a very high speed, 6,000 to 10,000 revolutions per minute. It is essential that this train of gearing run very quietly, so that makers of rival separators will not be able to say that the apparatus talks it own demerits.

To meet the requirements of this case, it was decided to design something that would apply to a standard machine, and at the same time produce the quality of work desired in goodly quantities. The attachment is put on to a No. 1 plain milling machine, bolting it to the table and locking the table in position, the necessary longitudinal travel being embodied in the attachment itself. The attachment is driven by connecting the Hooke's

* Presented at the Saratoga meeting (June, 1903) of the American Society of Mechanical Engineers, and forming part of Volume XXIV. of the *Transactions*.

joint of the machine to the end of worm-shaft on the fixture. The gear-cutter used is a standard or special shape, and is driven through a standard vertical spindle milling attachment. The blanks are held firmly at one end in a spring chuck closed with

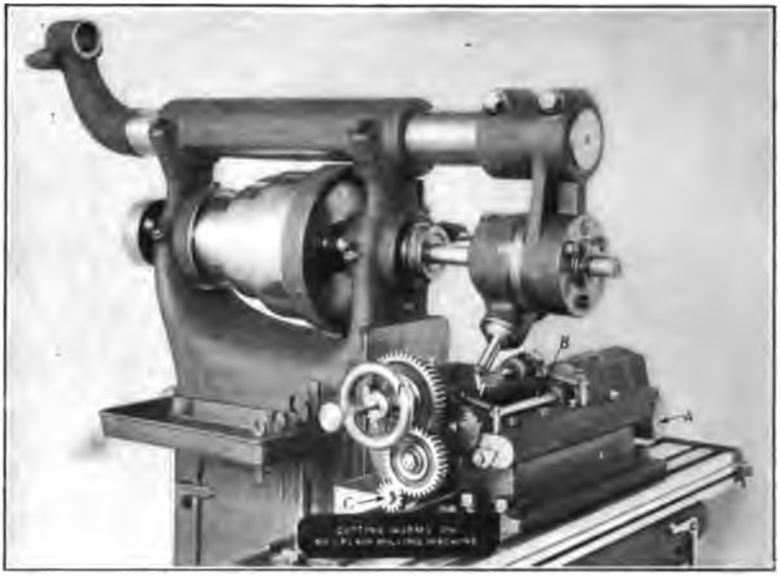


FIG. 300.

the hand-wheel F, and at the other in a female centre forming a part of the bracket H. The cutter is flooded with oil or soda water, and the chips and oil flow into the tank G to be strained and oil returned by the pump.

This "worm milling attachment," as it has been designated, is best shown in the general view in Fig. 300. It consists of a base bolted to the table, and carrying on its top a slide. The Hooke's joint connects to the worm-shaft A, and the latter to the cam-shaft B through a worm-wheel. On cam-shaft B are two disc-cams EE, which operate against the ends of screws D to throw the work into cutting position during forward travel and allow it to be pulled out of cut during the return. On shaft C is a swinging bracket HH, which carries a work spindle and tail-stock. Also on the cam-shaft B, in the housing at the right-hand end is a body-cam, which engages with a roller on a vertical pin fixed in the base of the attachment. Therefore as the cam-shaft rotates, the work is thrown up to the cutter or allowed to be drawn away at the proper instant at the end of the cut by a pair of spiral springs. The body-cam referred to travels the slide forward and backward by the cutter. The connection from worm-shaft A to shaft C is by a pair of spiral gears, dipping in oil. These gears are equal in diameter, but reduce the motion one-half through the relations of the angles of teeth. At the opposite end of the attachment there is a train of spur gearing from shaft C to the work spindle. So that as the Hooke's joint is driven, the blank is continuously rotated in one direction, and the cams before referred to produce the in and out and longitudinal movement of the work relative to the cutter.

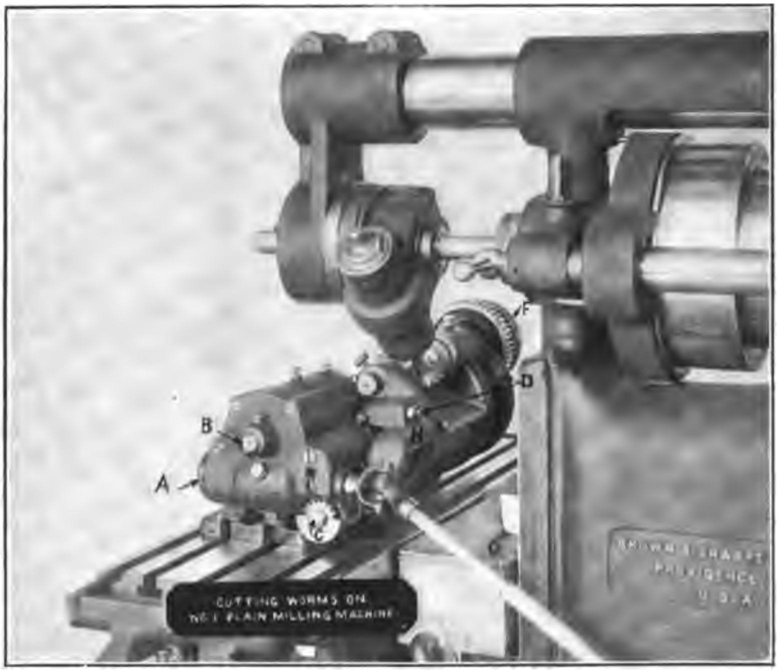


FIG. 301.

One of the peculiar features of this attachment is the method of accomplishing the indexing. The work is rotated continuously in one direction, and there is no indexing in the usual sense of the term. The body-cam and the gearing are so proportioned that the time of return of the cutter slide is exactly equal to the time of rotation of the blank through a certain fraction of the revolution. For instance, if the worm has seven teeth, the time allowed for returning the slide may be that required with the given gearing to rotate the blank four-sevenths of one revolution. The apparatus would therefore cut in this case every fourth tooth, and eventually all seven would be done. We might arrange this so as to cut every third tooth or every fifth tooth. Where there is an even number of teeth, say 8, we would cut every third, fifth, or seventh tooth, the point being that the number of teeth skipped must be prime to the number of teeth in the worm.

The cutting speeds for this work will of course depend upon the quality of stock employed, the same speeds evidently being possible as in a standard gear cutting machine. These would run say 25 to 30 feet per minute for tool steel, to 40 to 50 feet per minute for rough cut on soft machinery steel. Some people cut these out of the solid, full depth at one cut, driving slow enough to produce the quality of work they desire. I would recommend, however, taking two cuts and leaving about .008 of an inch for the finishing cut. For machinery steel I would run the cutting speed up as high as 120 feet per minute, and reduce the feed per revolution so as to make about the same feed per minute as before. The time of finishing one of these worms will vary considerably, but probably the average would run, where two cuts are used, about 14 minutes. I have cut one with seven teeth in eight minutes.

No. 156.

Have any new forms of flexible tubing been developed since the article in Vol. XII. of the *Transactions*, p. 197. If so, what is the form of joint and what diameters are made?

Percy A. Sanguinetti.—A flexible mettalic tubing possessing interesting mechanical features, having been recently brought to my notice, I am induced to present it to the Society. The tubing is manufactured in England and is made of copper or galvanized steel tape, in sizes from $\frac{5}{32}$ of an inch to 8 inches diameter; and to stand pressures from 100 to 6,000 pounds per square inch.

The illustration shows the way in which the tube is formed, and the manufacturer's description is, that as the tape is rolled, it forms a groove for the reception of a specially prepared asbestos wire thread packing, which is completely inclosed in the metal as it rolls, and remains fully protected from internal or external wear. This asbestos thread makes the tubing perfectly tight, while the interlocking feature induces a flexibility in the smaller sizes equal, and in the larger sizes far superior to rubber hose of the same dimensions and strength.

The uses to which the tubing may be applied, are as follows: copper is used chiefly for steam, and steel for hydraulic and pneumatic use, petroleum, naphtha, gas, acid, ammonia, paint, etc., while the lighter kinds are used for electric cable armoring, automobile horns, speaking-tubes, elevator leaders, etc.

The tubing can be used to connect lines of steam piping in place of slip or other expansion joints, or lines of piping that would be subject to derangement of any kind.

The amount of curvature that the tubing will withstand without straining varies with the size, and may be stated generally as follows: the smaller sizes, from $\frac{5}{32}$ of an inch to 1 inch, can be bent to a diameter of from 6 to 16 inches; up to 3 inches, 34 inches; and from 4 inches to 8 inches, 50 to 84 inches.

FIG. 302.

It is being arranged to have a piece of the tubing on exhibition at the meeting, closed at one end, and the other end attached to a hand-pump and pressure-gauge, for the purpose of giving an illustration of its behavior under pressure.

No. 157.

Is a *standard boiler*, for testing the comparative evaporation efficiency of various coals, feasible or desirable?

L. P. Breckenridge.—It has seemed to the writer that some information of value might be obtained relative to the comparative values of the various coals throughout the United States, if the different coals could all be tested in a standard boiler.

The installation of such a boiler in the different technical schools as a part of their laboratory equipment could easily be accomplished, provided a small and inexpensive type could be determined on as a standard.

The following proportions are suggested as suitable for such a standard boiler:

Vertical Tubular Type.

Diameter of boiler	36 inches.
Height " "	96 "
Diameter of furnace	31 "
Height " "	27 "
Thickness of shell	$\frac{1}{4}$ "
" " fire-box	$\frac{5}{16}$ "
" " heads	$\frac{7}{16}$ "
Length of tubes	69 "
Diameter of tubes	2 "
Number of tubes	68
Diameter of stack	15 "
Approximate weight of boiler complete	3,600 pounds.
Horse-power as usually rated	20
Probable cost	$200.00

A boiler such as described is an excellent piece of laboratory apparatus, and while it is perhaps not suited to every kind of coal, still it is thought that by the exercise of some judgment nearly all kinds of coal could be burned in it with success, especially if auxiliary draft apparatus be provided whereby the rate of combustion could be easily controlled over a wide range.

The internal condition of the boiler could always be maintained clean by arranging for the use of pure water either from a cistern or from returns from a heating system.

DISCUSSION.

Mr. Cary.—In criticising Professor Breckenridge's suggestion, concerning the adoption of a *standard boiler* for the purpose of obtaining information as to the comparative values of various coals, I must admit that I do so with some diffidence, knowing that he has had under his supervision (at the University of Illinois) a very extensive series of tests with Illinois coals collected from all parts of the State, the tests being made under several different boilers, both of the horizontal tubular and water tube types and under varying furnace conditions.

I cannot, however, refrain from expressing some surprise that he should offer a boiler of such design as he has described, in view of the fact that he has had such an extended experience, but, doubtless, he has some good reason for doing so, and I would be pleased to learn what his reason is.

It is generally known that when bituminous coal is thrown upon an incandescent fire bed in a boiler furnace that the fresh coal first becomes heated, and when a temperature of between 660 degrees and 870 degrees Fahrenheit is reached its volatile hydrocarbon gases are distilled off, and these gases rise into the furnace chamber above the fire bed and then pass on to an adjoining combustion chamber (when such a provision is made).

The principal hydrocarbon gas distilled off from bituminous coal is marsh gas (CH_4), and careful experiment has shown that its temperatures must be raised to between 1,300 degrees and 1,400 degrees Fahrenheit before its ignition will take place, and if any lesser temperature exists in the furance or combustion chamber, this gas will not unite with the oxygen present; or, in other words, combustion will not take place, and this most available fuel constituent will then pass up the chimney with the resulting loss in fuel economy.

On the other hand, supposing our marsh gas has, for the moment, been raised to its ignition temperature in the presence of an ample oxygen supply, and then, before sufficient time has elapsed to complete its combustion, suppose its temperature to be suddenly lowered below this degree. At first complete combustion will occur, resulting in the production of carbonic acid and water vapor; then, as its temperature is slightly lowered, we will find the hydrocarbon splitting up and its hydrogen alone uniting with the oxygen present, forming superheated steam while the liberated carbon will pass off unconsumed, as soot; and finally, as the temperature falls still lower, the combustion of our marsh gas ceases entirely, and a total waste of available heat occurs, due to the non-combustion of the gas.

Some appreciation of the losses due to the incomplete combustion of marsh gas may be had by considering that

One pound of marsh gas burned to carbon dioxide and water will generate..23,513 B.T.U.
One pound of marsh gas burned to carbon nonoxide and water will generate..16,184 B.T.U.

and

One pound of marsh gas burned to water, with its carbon unconsumed, will generate..........................15,525 B.T.U.

From the above statements, and with a knowledge that all other hydrocarbon gases distilled from bituminous coal behave similarly under like conditions, we see that for the purpose of obtaining economcal results it is essential that:

First. The area of the grate should be of such dimensions as to allow a bright incandescent fire surface to be maintained to receive each fresh charge of coal, and when we find such a bright fuel bed existing, we are pretty sure to find an ample penetration of air (from below the grates) to furnish the required air supply needed for the combustion of the volatile gases in the furnace and combustion chamber.

This statement might be somewhat qualified by stating further that unless a very small quantity of coal is very thinly sprinkled over the surface of the fire bed the air supply passing through the fire bed will have to be supplemented from some other source for a short time following the charging of the fresh fuel.

Secondly. We must constantly maintain a temperature in our furnace and combustion chambers above that degree known as the critical temperature of combustion of the volatile gases until these gases are completely consumed.

A further condition, which must not be overlooked in this consideration, is the provision of a furnace and combustion chamber of ample size to meet the fuel requirements.

When a coal contains a large percentage of volatile matter, large chambers should be provided in which the air supply and volatile gases can find ample facilities for thorough intercommingling before they come in contact (to any great extent) with the comparatively cold boiler parts, and such chambers should be so designed as to provide a sufficiently slow passage of these volatile gases from the furnace to the position where they enter the interior of the boiler, to allow their complete combustion to take place before the burning gases are chilled (in the interior of the boiler) below their temperature of ignition.

With this statement of required conditions before us, let us examine the boiler offered by Professor Breckenridge.

We find in this vertical tubular boiler a grate 31 inches in diameter, which has a surface of about 5¼ square feet. This grate surface cannot be extended to meet special fuel requirements, and it can only be contracted by an undesirable arrangement of firebricks placed around the outer circumference of the furnace. Thus we see that in order to vary our fuel consumption we must either increase, or decrease, the thickness of our fuel bed, which practice does not always lead to the best results.

One of the points which should be determined by use of an experimental boiler is the best depth of fuel bed under given draft condition to secure the best results.

It is true that we can, with proper arrangements, vary our draft pressure when using this boiler, but such variation in this case must be made by force of necessity in order to accomplish the combustion of a desired amount of coal.

In experimental work, we should not be forced by such arbitrary conditions to alter our draft pressure, as this will limit our scope of obtainable information. It is certainly most desirable for us to know the minimum draft pressure under which a given kind of coal can be burned with economical results.

In a boiler of this type the furnace and combustion chambers must necessarily be one, and their volumetric capacity must be limited by the internal diameter of the water leg. Further, the volatile gases distilled from the fresh coal are not only brought into immediate contact with the chilling water surfaces closely surrounding them, but they are hurried rapidly upwards into the vertical tubes of the boiler, in which their combustion is most effectually suppressed.

A Dutch oven (or extended furnace) can be constructed so as to deliver its gases into the furnace chamber of this boiler, but vertical boilers thus set usually have no water leg, the heads of such boilers usually being placed on the extreme ends of the shell.

A boiler of such construction presents a very large surface for radiation, and besides, when bad feed water is used, the lower (or fire) head soon has its interior coated, and leaky tubes result, while many criticise, with good reason, the arrangement of the upper head, which is not submerged, and, consequently, exposed to the action of the heat, which sometimes causes leaky tubes in this upper tube sheet.

By referring to reliable tests, it will be found that a boiler of this type has not, as a rule, given results equal to the performance of other types of boilers, where the volatile matter in the coal used exceeds 20 per cent.

The best form of experimental boiler is one of the horizontal type, and it should be constructed with an external fire-box so arranged that the size of the grate surface can be easily altered to any reasonable desired extent, while the grate itself should be capable of being raised or lowered, so as to increase or decrease vertically the size of the furnace chamber.

It is also desirable to have adjoining this furnace chamber a combustion chamber arranged to receive fire-brick or checker work, or baffle or wing walls as has been described by Prof. E. A. Hitchcock in his paper on "The Experiment Boiler of the Ohio State University," presented at this meeting.

Provision should also be made to allow the insertion of fire-brick arches over the furnace and combustion chamber of such a boiler, as the best results cannot be obtained with coals running high in volatile matter without them.

Should we attempt to test all coals under one fixed set of furnace conditions, we would be unable to obtain information from the results of such tests which would allow a fair comparison to be made of their relative merits. Each class of coal should be tested under furnace conditions productive of the best results, and relative information gathered in any other way will only lead to the further contribution of misinformation on this subject, which already exists.

I have thus far, for the sake of argument, discussed this subjest as though I thought that a boiler was necessary to assist in obtaining information regarding the relative value of coals. Such a fact is, however, diametrically opposite to my opinion in this matter.

The results obtained from carefully conducted tests with a Mahler Bomb calorimeter taken in connection with accurate chemical analysis of the coal (both proximate and ultimate) will certainly give us an excellent idea of the comparative values of different coals.

In such work it is well to check the results obtained by the calorimeter with the calorific value of the coal as determined by the Dulong formula, the use of which will of course require an ultimate analysis of the coal. If these two results are approximately the same, we may safely conclude that the calorific value obtained is accurate.

Generally speaking, the calculations from chemical analysis should give slightly higher results than those obtained by calorimeter determinations, since most of the errors which are made in the analysis tend to increase the calculated values, while the errors made with the calorimeter tend to diminish these values.

From our proximate analysis we can obtain the necessary information to properly classify the coal, and from it we also learn how much of the fuel must be burned in the gaseous state and how much will be burned directly from the solid state, and such information will aid us materially in the proper design of our furnaces and combustion chambers.

With the knowledge thus obtained, and at the same time knowing our limitations as to the application of the most desirable designs of furnace and boiler in any one plant, we should determine separately the percentage of efficiency of our furnace and the percentage of efficiency of our boiler to be used, and the product of these two efficiencies will give us the total combined percentage of efficiency of both boiler and furnace. We then have merely to multiply this product by the calorific value of our coal in order to arrive at the evaporative results which may be expected under the considered conditions.

*Prof. L. P. Breckenridge.**—The writer realized that the type of boiler suggested was open to the objections presented by Mr. Cary. The reason why such a type was suggested was because of its cheapness, and unless some cheap form could be adopted the entire plan would fail.

It was not the thought of the writer that this plan of comparing coals should in any way take the place of chemical analysis or of the calorimeter. It did seem, however, that, as before stated, "some information of value might be obtained" if the various coals could all be tested in the same type of boiler.

The use of the term "Standard Boiler" in this connection was perhaps unfortunate. The writer had in his mind one of the Standard types of boilers as manufactured rather than such a boiler as would be designed for the purpose of making a series of standard tests.

---

* Author's Closure, under the Rules.

FIG. 303.

No. 1005.

ROBERT FULTON MEMORIAL.

It will be recalled that, at the death of Mr. Robert Fulton in 1815, his body was interred in Trinity Churchyard, in New York City, in the vault belonging to the Livingston family. It had been felt by the American Society of Mechanical Engineers that it would be very fitting to recognize the debt which the profession of engineering owed to Mr. Fulton for making the problem of propulsion on the water by steam a commercial success by a suitable monument in the churchyard, whereby the obligation might be recognized on the one hand, and the fame of Mr. Fulton be made more enduring.

To this end the Society appointed a committee, consisting of Mr. Gus C. Henning, Chairman, Mr. H. H. Suplee and Mr. C. W. Hunt, to confer with the corporation of Trinity Church with respect to the erection of such monument, at the expense of the Society. As the result of the work of this Committee, an arrangement was made for an eligible location on the Rector Street side of Trinity Churchyard, and the consent of the descendants of Mr. Fulton was secured to the taking of the necessary steps to dedicate this memorial with suitable ceremonies. The date chosen for the exercises in connection with the monument was the afternoon of Thursday, December 5, 1901, during the continuance of the Twenty-second Annual Meeting of the Society.

The exercises of the day consisted of addresses by Chief Engineer B. F. Isherwood, Rear-Admiral George W. Melville and Professor R. H. Thurston, in commemoration of the achievements of Mr. Fulton on the professional and secular side. These addresses were delivered in the Board room of the Real Estate Exchange in the basement of the Trinity Buildings, on the north side of the churchyard. Adjourning then in a body, the Society attended a full choral service following the ritual of the Episcopal Church in the nave of Trinity Church.

The service was conducted by the Rev. Morgan Dix, Rector of

Trinity Parish, and the sermon was delivered by the Rev. Robert Fulton Crary, of Poughkeepsie, New York, grandson of Mr. Robert Fulton. Following the close of the service, the members

FIG. 304.

of the Society with their guests and the relatives of Mr. Fulton who could be reached, filed into the churchyard past the monument and the exercises were over.

It added particular interest to the occasion that among the

The design of the monument is shown in the accompanying illustration (Fig. 305). The inscription is as follows:

Erected to the Memory of
ROBERT FULTON,
Born 1765. Died 1815.
By
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS,
1901.

It is surmounted by a bas-relief medallion (Fig. 306) taken from the best authentic sources, and based mainly upon a portrait in the possession of the Society and hanging on its walls, which has been

FIG. 306.

stated to be a portrait of himself by Mr. Fulton, at the time he was making portrait painting his special avocation. A reproduction of this portrait is shown in Fig. 303. On the back of the base of the monument, where it can be distinctly read from the Rector Street side of the churchyard, stands the simple word "FULTON."

The Committee had cast in bronze the reproduction of a Robert Fulton drawing which is shown in Fig. 307, and had intended to place this on the rear of the shaft to correspond with the medallion. It was finally decided to omit the reproduction and to put it to other uses.

It has been thought advisable as a matter of record, that an appendix to the Society's Transactions should contain the full religious service and the addresses. These in their order follow:

TRINITY CHURCH, NEW YORK.

FORM OF SERVICE, DECEMBER 5TH, 1901, AT 3 O'CLOCK P.M. ON THE OCCASION OF THE UNVEILING OF A MONUMENT ERECTED IN THE CHURCH YARD BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS TO THE MEMORY OF ROBERT FULTON.

ORDER OF SERVICE.

OPENING VOLUNTARY, { Largo e mesto, Opus 10, No. 3 } .... *Beethoven*

PROCESSIONAL, Hymn 452............(Tune Pleyel).................. *Pleyel*

Children of the Heavenly King,
As ye journey, sweetly sing!
Sing your Saviour's worthy praise,
Glorious in His works and ways!

We are travelling home to God,
In the way the fathers trod:
They are happy now, and we
Soon their happiness shall see.

Lift your eyes, ye sons of light!
Sion's city is in sight:
There our endless home shall be,
There our Lord we soon shall see.

Fear not, brethren; joyful stand
On the borders of your land;
Jesus Christ, your Father's Son,
Bids you undismayed go on.

Lord, obediently we go,
Gladly leaving all below;
Only Thou our Leader be,
And we still will follow Thee.

In the name of the Father, and of the Son, and of the Holy Ghost. Amen.

Thou, O God, art praised in Sion: and unto thee shall the vow be performed in Jerusalem. *Psalm lxv.* 1.

The souls of the righteous are in the hand of God, and there shall no torment touch them. *Wisdom iii.* 1.

The children of Thy servants shall continue: and their seed shall stand fast in Thy sight. *Psalm cii.* 28.

Ver. The Lord be with you.

℟. And with thy spirit.

Let us pray.

Our Father, who art in heaven, Hallowed be thy Name. Thy kingdom come. Thy will be done on earth, As it is in heaven. Give us this day our daily bread. And forgive us our tresspasses, As we forgive those who tresspass against us. And lead us not into temptation; But deliver us from evil: For thine is the kingdom, and the power, and the glory, for ever and ever. Amen.

Ver. O Lord open thou our lips.
℟. And our mouth shall show forth thy praise.
Ver. O God, make speed to save us.
℟. O Lord, make haste to help us.

Glory be to the Father, and to the Son, and to the Holy Ghost; As it was in the beginning, is now, and ever shall be, world without end. Amen.

Praise ye the Lord.

The Lord's name be praised.

PSALM xciii.. *Attwood*

The Lord is King, and hath put on glorious apparel: the Lord hath put on his apparel, and girded himself with strength.

He hath made the round world so sure: that it cannot be moved.

Ever since the world began, hath thy seat been prepared: thou art from everlasting.

The floods are risen, O Lord, the floods have lift up their voice: the floods lift up their waves.

The waves of the sea are mighty, and rage horribly: but yet the Lord, who dwelleth on high, is mightier.

Thy testimonies, O Lord, are very sure: holiness becometh thine house for ever.

PSALM cxii.. *Walmisley*

Blessed is the man that feareth the Lord: he hath great delight in his commandments.

His seed shall be mighty upon earth: the generation of the faithful shall be blessed.

Riches and plenteousness shall be in his house: and his righteousness endureth for ever.

Unto the godly there ariseth up light in the darkness: he is merciful, loving, and righteous.

A good man is merciful, and lendeth; and will guide his words with discretion.

For he shall never be moved: and the righteous shall be had in everlasting remembrance.

He will not be afraid of any evil tidings: for his heart standeth fast, and believeth in the Lord.

His heart is stablished, and will not shrink: until he see his desire upon his enemies.

He hath dispersed abroad, and given to the poor: and his righteousness remaineth for ever; his horn shall be exalted with honour.

The ungodly shall see it, and it shall grieve him: he shall gnash with his teeth, and consume away; the desire of the ungodly shall perish.

PSALM cxvii.. *Cooke*

O praise the Lord, all ye heathen: praise him, all ye nations. For his merciful kindness is ever more and more toward us: and the truth of the Lord endureth for ever. Praise the Lord.

THE LESSON. Ecclesiasticus xxxix. 1–10.

He that giveth his mind to the law of the most High, and is occupied in the meditation thereof will seek out the wisdom of all the ancient, and be occupied in prophecies.

He will keep the sayings of the learned men: and where subtil parables are, he will be there also.

He will seek out the secrets of grave sentences, and be conversant in dark parables.

He shall serve among great men, and appear before princes: he will travel through strange countries; for he hath tried the good and the evil among men.

He will give his heart to resort early to the Lord that made him, and will pray before the most High, and will open his mouth in prayer, and make supplication for his sins.

When the great Lord will, he shall be filled with the spirit of understanding: he shall pour out wise sentences, and give thanks unto the Lord in his prayer.

He shall direct his counsel and knowledge, and in his secrets shall he meditate.

He shall show forth that which he hath learned, and shall glory in the law of the convenant of the Lord.

Many shall commend his understanding; and so long as the world endureth, it shall not be blotted out; his memorial shall not depart away, and his name shall live from generation to generation.

Nations shall show forth his wisdom, and the congregation shall declare his praise.

CANTATE DOMINO, in E flat.. *Garrett*

O sing unto the Lord a new song: for he hath done marvellous things.

With his own right hand, and with his holy arm: hath he gotten himself the victory.

The Lord declared his salvation: his righteousness hath he openly showed in the sight of the heathen.

He hath remembered his mercy and truth toward the house of Israel: and all the ends of the world have seen the salvation of our God.

Show yourselves joyful unto the Lord, all ye lands: sing, rejoice, and give thanks.

Praise the Lord upon the harp: sing to the harp with a psalm of thanksgiving.

With trumpets also and shawms: O show yourselves joyful before the Lord, the King.

Let the sea make a noise, and all that therein is: the round world, and they that dwell therein.

Let the floods clap their hands, and let the hills be joyful together before the Lord: for he is come to judge the earth.

With righteousness shall he judge the world: and the people with equity.

I believe in God the Father Almighty, Maker of heaven and earth: And in Jesus Christ his only Son our Lord: Who was conceived by the Holy Ghost, Born of the Virgin Mary: Suffered under Pontius Pilate, Was crucified, dead and buried: He descended into hell; the third day he rose again from the dead: He ascended into heaven, And sitteth on the right hand of God the Father Almighty: From thence he shall come to judge the quick and the dead.

I believe in the Holy Ghost: The holy Catholic Church; The Communion of Saints: The Forgiveness of sins; The Resurrection of the body: And the Life everlasting. Amen.

Ver. The Lord be with you.
℟. And with thy spirit.
Let us pray.

Ver. O Lord, show thy mercy upon us.
℟. And grant us thy salvation.
Ver. It is the Lord that commandeth the waters:
℟. It is the glorious God that maketh the thunder.
Ver. Thy way is in the sea, and thy paths in the great waters:
℟. And thy footsteps are not known.
Ver. The Lord sitteth above the water flood:
℟. And the Lord remaineth a King for ever.
Ver. The Lord shall give strength unto his people.
℟. The Lord shall give his people the blessing of peace.
Ver. O God, make clean our hearts within us.
℟. And take not thy holy spirit from us.

The Collect.

Almighty God, give us grace that we may cast away the works of darkness, and put upon us the armour of light, now in the time of this mortal life, in which thy Son Jesus Christ came to visit us in great humility; that in the last day, when he shall come again in his glorious majesty to judge both the quick and the dead, we may rise to the life immortal, through him who liveth and reigneth with thee and the Holy Ghost, now and ever. Amen.

A Collect for Peace.

O God, from whom all holy desires, all good counsels, and all just works do proceed; Give unto thy servants that peace which the world cannot give; that our hearts may be set to obey thy commandments, and also that by thee, we, being defended from the fear of our enemies, may pass our time in rest and quietness; through the merits of Jesus Christ our Saviour. Amen.

We bless Thy holy Name, O Lord, for the names and honour of those who having done Thy will and finished their work which Thou gavest them to do, have departed out of this world in Thy faith and fear, and especially for Thy servant whom we remember and commemorate before Thee this day. And we pray Thee graciously to accept the dedication of the monument now set up in this churchyard in memory of our brother. May his name be held in everlasting remembrance, and his praise throughout all generations. And grant to us, Thy humble servants, that by Thy help we may glorify Thy holy Name in all our works begun, continued, and ended in thee, and at last, with Thy people, be made partakers of peace, and rest in Thy presence forever more, through Jesus Christ, our Lord.

The grace of our Lord Jesus Christ, and the love of God, and the fellowship of the Holy Ghost, be with us all evermore. Amen.

HYMN 418....................(Tune St. Anne)....................*Croft*

O God, our help in ages past,
  Our hope for years to come,
Our shelter from the stormy blast
  And our eternal home:

Under the shadow of Thy throne
  Thy saints have dwelt secure;
Sufficient is Thine arm alone,
  And our defense is sure.

Before the hills in order stood,
  Or earth received her frame,
From everlasting Thou art God,
  To endless years the same.

A thousand ages in Thy sight
  Are like an evening gone;
Short as the watch that ends the night
  Before the rising sun.

Time, like an ever-rolling stream,
  Bears all its sons away;
They fly, forgotten, as a dream
  Dies at the opening day.

O God, our help in ages past,
  Our hope for years to come,
Be Thou our guide while life shall last,
  And our eternal home.

ADDRESS BY THE REV. ROBERT FULTON CRARY, D.D.

BENEDICTION.

RECESSIONAL HYMN 414..........(Tune St. Oswald)..............*Dykes*

Guide me, O Thou great Jehovah,
  Pilgrim through this barren land,
I am weak, but Thou art mighty:
  Hold me with Thy powerful hand.

Open now the crystal fountains
  Whence the living waters flow;
Let the fiery, cloudy pillar
  Lead me all my journey through.

Feed me with the heavenly manna
  In this barren wilderness;
Be my sword, and shield, and banner,
  Be the Lord my Righteousness.

When I tread the verge of Jordan,
Bid my anxious fears subside;
Death of death, and hell's destruction,
Land me safe on Canaan's side.

CLOSING VOLUNTARY...... { Finale from Theme and variations in A flat } ....*Thiele*

ADDRESS READ IN NEW YORK CITY BY GEORGE W. MELVILLE, REAR ADMIRAL AND ENGINEER-IN-CHIEF, U. S. N., DECEMBER 5, 1901.

ROBERT FULTON.

"Death makes no conquest of this conqueror;
For now he lives in fame, though not in life."*

"Here the reward stands for thee—A chief seat
In fame's fair sanctuary, where some of old,
Crown'd with their troubles, now are here enroll'd
In memory's sacred sweetness to all ages." †

Ladies and Gentlemen: We are assembled here to do honor to the memory of a Great American and a Great Engineer. To the memory of one whose work led, in its development, to the utmost benefits and blessings to mankind. Without exaggeration, it can be truly said, that among the world's foremost benefactors stands Robert Fulton, the American Engineer, whose monument we are dedicating to-day.

It is most appropriate that this monument should be reared in the metropolis of the Western World, where his greatest triumphs were achieved, and where he rests amidst the sights and sounds of that prosperity which is largely the outgrowth of his genius and perseverance. But the prosperity of New York is only a part of the prosperity of the whole world that has come from the development of Steam Navigation, which, in its realization, far surpasses the most eager dreams of Fulton and his contemporaries for the expansion of commerce, the closer communication between nations, and the more intimate intercourse among men.

---

* Quotation 1.—Shakespeare, "Richard III."
† Quotation 2.—Middleton's "Triumph of Love and Antiquity."

When we reflect upon the changes produced by the successful application of steam to navigation—when we attempt to span mentally the entire period from the beginning of this mighty industry down to its present magnificent fruition—we realize that the advance of time has brought almost another world. Upon the sea to-day are borne great fleets of swift and safe commerce carriers; and to-day powerful steam warships proudly fly the flag of Nations in all quarters of the globe. Repeatedly the records for speed have been broken by the Transatlantic liners; and the close of the past Century witnessed the triumphant sweep over the ocean of a COLUMBIA and of an OREGON.

The journey across the Atlantic, which a hundred years ago was a serious undertaking, is now a pleasure-trip which our busy men start upon at a few hours' notice, and which almost every fashionable society woman counts as a part of her regular duties.

Steam Navigation has enabled the inhabitants of the different countries to come into the closest touch with each other by the enormous increase of mail facilites, and by the interchange of literature. It has practically abolished climatic conditions as far as food products are concerned; and has made it possible for people in every country to enjoy the products of every other. This great benefit is shared by all classes of society.

Not only has Steam Navigation made more pleasant the lot of people on shore, but it has completely changed the life of people on board ship. With the development of steam to the arts, the modern vessel is able to carry fresh food; to have absolutely pure water, the best of light and thorough ventilation—together with comfortable warmth. How great a change this is from the conditions of a hundred years ago can be only fully realized by those who have had some experience with sailing vessels built in the early part of the last century.

Though Fulton's achievements were not at first thoroughly understood nor appreciated by his countrymen, and though he has not been always given that credit which he deserves by foreign writers, it may be said that the success of Fulton in the practical establishment of Steam Navigation was so marked an event in history, that since his death his memory has been honored by the American people and his merits generally recognized the world over. Of him there have been scores of memorials written; and in different periods of our history Government and Merchant vessels have borne his name. Other substantial marks of respect have been paid to his memory. Here, in New York, you have daily reminders of Fulton in the "*Fulton* Ferry" (which he started, and which up to the time of the construction of the Brooklyn Bridge was the chief means of transportation between New York and Brooklyn), and in *Fulton* Street and in the *Fulton* Market. But while there is actually needed, perhaps, no further expression of our appreciation of his greatness to keep him in remembrance, it is meet that we should at last erect this monument to his memory. As engineers we feel it especially incumbent upon us to discharge this loving duty.

Toward the close of the Eighteenth Century, when the Steam Engine had but lately been sent forth on its world-wide mission by its master, it is natural that the thoughts and energies of many men should turn to the application of so marvellous a factor for material development—a factor fraught with such practical promise. Connected with the introduction of that important branch of the steam engine's application—Steam Navigation—history discloses a cluster of inventors, engineers or mechanics, of different nationalities (including a number of Americans besides Robert Fulton) of varying force of character, originality, mechanical aptitude and business ability.

It is not likely, after the lapse of history, when the merits of the different men who attempted to construct a commercially successful steamboat have been thoroughly sifted, that our patriotism would obscure our judgment, and that we should laud Fulton at the expense of others. It is sufficient to say that Fulton was aided in his work by the efforts and partial success of those who had gone before him, and by the general scientific knowledge and engineering experience of his time, as well as by the acquaintance of some of the most able and enterprising men who were engaged in the solution of the world's problems, including Watt himself. He had also the financial aid and the friendship of his fellow-countryman, Chancellor Livingston, much in the same way that Watt had the material support and encouragement of Mr. Boulton.

But these advantages of themselves could not have insured success, which was the result of Fulton's progressive and courageous spirit, his adaptive and resourceful mind, his originality, practical judgment and unremitting labor.

Without doubt, Fulton must be acknowledged to have made that valuable contribution to the world's progress—the commercial establishment of Steam Navigation.

The claims of any man, of any Nation, cannot take from the

American Engineer, Fulton, that success which the unanswerable logic of his deeds awards him.

"One thing is forever good:
That one thing is success."

When rightly used, the originative faculty is the glory of mankind. It is only by scientific discovery, great invention, and progressive engineering that material advance can be made, and civilization be carried onward. For man, the best knowledge is that which is most useful to him, and he who makes successful mechanical applications and improvements is a world-wide philanthropist.

The grand dreamer in Mechanics burns with the true spirit of progress. Unfortunately, from habits of abstract thought and insufficient amount of practical experience—which are indeed almost inseparable from his genius—the Mechanical Seer often is unable to place his discovery within the reach of humanity, and it therefore frequently remains for the more practical inventor and engineer to aid him in interpreting its mechanical advantages and exhausting its commercial possibilities.

Our present conception of the term "Invention" is much wider and more definite than in the past, and it is seen to be more closely connected with scientific experiment and *engineering efficiency* than was formerly supposed. The Inventor in the truest sense of the term is he who, besides having the originative faculty, possesses wide scientific knowledge, and practical skill in the design of, and experience with, existing forms of machinery. In addition to these qualities, for an inventor to achieve commercial success with his invention, there must be a natural demand for it; and he must possess the courage and perseverance, the financial means, and the practical ability to put it upon a business basis, or else must entrust it wholly or partly to the hands of others to do so.

The necessity for all of these qualities becomes greater as the machine becomes more complex.

It is, moreover, now thoroughly appreciated that in the design of machinery, the most exacting exercise of the inventive faculty is required—inasmuch as here the mind is working within narrower limits of practicability and a more definiteness of thought and fixity of attention are needed. The designer is approaching the actual construction, and further on, the actual operation, of the machine. Such use of the imagination takes the most sound and disciplined intellect; and the courage and character of the man will be here shown in the results of his work—whether all the details of development have been worked out, or whether the machine, through half-heartedness and slip-shod methods on the part of the designer, falls short of its possibilities.

Generally speaking, Fulton's claims as the first inventor of the practical steamboat cannot be disputed, since it proved its utility in actual service. As a rule, a great mechanical invention is the outgrowth of the combined efforts of several inventors of more than one Nation, and in a general sense may be said to be common scientific knowledge; but to the man who actually makes a commercial success of an invention, due credit always must be given. Fulton commercially created the steamboat.

There can be no doubt of Fulton's power of originality, which (besides being evidenced by his work of proportioning the machinery to the hull of his vessels, and by the improvements which he made to each successive boat as it was built), may be seen in the work of his whole life, which was in great part taken up with invention and the projection of plans for the world's welfare.

Fulton possessed scientific knowledge and practical skill, was a progressive engineer, and his great work in the establishment and subsequent improvement of the *commercial steamboat* was built upon a firm foundation.

In his methods, we note the most careful procedure and the most approved ways and means to attain the results desired. He did not trust to vague theory, but worked out all details and thoroughly tried everything that might be in doubt before attempting to introduce it into actual use.

In securing the confidence and aid of friends, Fulton may be said to have had "good fortune," which is at best a most unsatisfactory and indefinite term; but all other requisites for the commercial success of a marked and timely application in the use of the steam engine Fulton either naturally possessed or else acquired by his industry.

Let us not permit our knowledge of the present advanced state of Marine Engineering efficiency and practice to dim our conception of Fulton's great work.

Let us recognize his great achievement.

Let us give all honor to Fulton who by his courage, energy and determination; by his knowledge, skill and practical enterprise—through combat and stress, through trial and labor, through discouragement and inappreciation—overcame opposition, beat down the barriers of conservatism, and turned cold indifference into fervid enthusiasm, and sneering ignorance into unfeigned wonder.

As one possessing the power of invention—or that which is often its practical equivalent, great ability as a progressive engineer and as a business man—Fulton lives in the fame that he so justly earned.

I have dwelt at some length upon Fulton's share in the introduction of the commercial steamboat, since in going through many old memorials and records of his achievements, glowing with appreciation of his greatest work (to which memorials and records we of this day are indebted for the knowledge of the detailed facts and circumstances attending Fulton's life and labors), one is impressed with the truth that, in some cases, his claims as the first inventor of the practical steamboat might have been put forth more positively. In the light of a more thorough realization at the present time of the intimate connection between the inventor, the progressive engineer, and the business man—Fulton's genius can be now more generally discerned.

Robert Fulton was born in Lancaster County, Pennsylvania, in 1765. At an early age he evinced talent as an Artist, and by the time he was 21 had achieved such success in painting that he was able to buy a farm for his widowed mother. On the advice of friends, he then went to England, to seek aid from that famous American, Benjamin West, in the further development of his talent for painting. After studying with Mr. West for several years, Fulton started out on his independent career as an Artist.

Soon making the acquaintance of several men of science and mechanical ability, the spirit of his true genius—that of Mechanics—which had been sleeping, awoke and urged him onward to the fulfilment of his destiny. In his earliest days, Fulton's true bent had asserted itself. As a boy he had fashioned a paddle wheel worked by a crank to save himself and his companions the fatigue of poling their boat in their youthful fishing trips on the Conestoga. Moreover, much of his spare time as a lad had been spent among the artisans in the workshops near his home; and before adopting the career of an Artist he had learned the trade of a watchmaker.

Seven years after his arrival in England, we find Fulton, then only 28 years of age, thoroughly impressed with the idea of the practicability of the steamboat to which so much of his best thoughts and energies were devoted throughout a great part of the remainder of his life. From views expressed by Fulton, about this time (1793), in a letter to Earl Stanhope, on the practicability of a plan for Steam Navigation—it is the opinion of competent authorities that had Fulton been given the opportunity to then test such views, the commercial steamboat would have been a fact ten years prior to the success of the CLERMONT which was launched in 1807.

By 1795, having added to his stock of mechanical knowledge, and won honors as an inventor, Fulton was a Civil Engineer and was writing extensively on technical subjects. He was particularly interested in inland navigation and appreciated its value as a means for the internal development of the United States.

Crossing the channel to France—in 1797 he formed the acquaintance in Paris of Mr. Barlow, who became his life-long friend. At this time, besides pursuing other studies, Fulton gained a better knowledge of mathematics and physics. It was while in Paris that Fulton experimented with submarine explosives and torpedo boats. When engaged in experimenting with torpedoes, a man possessing such practical judgment as Fulton must have realized that these weapons could never prove of great value as long as the vessel using them was dependent on the wind, so that we find him in 1801 again turning to the effort to make the steamboat a success.

These efforts, with the encouragement and active co-operation of his friend Chancellor Livingston, were continued at different times, both in France and England, up to the date of Fulton's return to the United States, which was in 1806. He then worked steadily on his great project, and shortly after was rewarded with success.

It was in the early part of the year 1807 that the CLERMONT —fitted with one of Boulton and Watt's engines which Fulton had ordered from England before he left for the United States— was launched, from the building yard of Charles Brown, on the East Hudson. At one o'clock, on the seventh day of August, 1807, the CLERMONT began her first trip from New York to Albany.

In a letter to Mr. Barlow, Fulton describes this memorable trip. He says:

"My steamboat voyage to Albany and back has turned out rather more favorable than I had calculated. The distance from New York to Albany is one hun-

dred and fifty miles; I ran it up in thirty-two hours and down in thirty. I had a light breeze against me the whole way, both going and coming, and the voyage has been performed wholly by the power of the steam engine. I overtook many sloops and schooners beating to windward, and parted with them as if they had been at anchor. The power of propelling boats by steam is now fully proved. The morning I left New York there were not, perhaps, thirty persons in the city who believed that the boat would ever move one mile an hour, or be of the least utility; and while we were putting off from the wharf, which was crowded with spectators, I heard a number of sarcastic remarks. This is the way in which ignorant men compliment what they call philosophers and projectors. Having employed much time, money, and zeal in accomplishing this work, it gives me, as it will you, great pleasure to see it fully answer my expectations. It will give a cheap and quick conveyance to the merchandise on the Mississippi, Missouri, and other great rivers which are now laying open their treasures to the enterprise of our countrymen; and although the prospect of personal emolument has been some inducement to me, yet I feel infinitely more pleasure in reflecting on the immense advantage that my country will derive from the invention, . . ."

This voyage established Steam Navigation, and the CLERMONT henceforth made regular trips between New York and Albany.

The CLERMONT was of 160 tons, was 133 feet long, 18 feet beam and 7 feet deep. The paddle wheels were 15 feet in diameter, with buckets 4 feet long, with a dip of 2 feet. Later her keel was lengthened to 140 feet.

Once the Steamboat became a commercial fact, Fulton was too thorough an Engineer to consider his work as accomplished, but immediately began to remedy all defects, which materially increased the CLERMONT's efficiency. And, as each new boat was put into service on the Hudson, she was an improvement over the one preceding.

Chancellor Livingston was still associated with Fulton, and in 1811 they built and put into service the first steamboat on the Mississippi, which was named ORLEANS.

So well was the work builded by Fulton that we may say that in its basic principles, it still lives—greatly developed it is true, but still not so changed that anyone could venture to declare that Fulton's share was of little value.

As a member of that profession which Fulton may be said to have founded—Marine Engineering—I feel it a peculiar honor for me to pay tribute to his genius. As engineers all of us can learn a great lesson from Fulton's labors—that of progressiveness—of not resting content until the full measure of efficiency, within the limits of safety and economy, has been obtained from each and every one of our works, which is the true test of their worth; and the highest honor that we can pay to his memory is for us to endeavor constantly to keep the profession of Engineering in the forefront of progress and thus add lasting benefits and blessings to the world.

The engineer's labors, taken in connection with the advance of science and its marked application (which are themselves often equivalent to Engineering in its highest expression), form the basis of all material success in both Peace and War—of all social progress. Perhaps it is this fact of the Engineer being at the basis of civilization that has made it take so long to "discover" him, *but there can be no doubt of his existence now.* To-day there is a word ringing around the world—it is ENGINEER. Thousands of eyes are turned upon him, and he is the object of the closest scrutiny. Amidst such public notice, it is natural that the Engineer should be far more conscious of what is required of him than he was in the past; and he is at present regarding himself most earnestly. He does not do this merely to dwell with complacency on his achievements, nor to exaggerate its importance to human welfare (though he may take a proper pride in this); but he is subjecting himself to the most searching analysis to get a fuller realization of his duties and responsibilities and to thus attain to the greatest possible height of usefulness.

The modern American engineer is wedded to the business world, is an industrial leader, and is a true political economist. He is vitally connected with the efficiency of military organizations, holds a high place in the Army or Navy, and is particularly fitted to understand and apply the principles of War.

Fulton was a member of the original family of American Engineers, and the American engineer of the hour is his direct descendant. Fulton was an engineer of character, mindful of his duty and responsibility; an engineer who strove to promote the welfare of his country in Peace and War; an engineer who realized the importance of the organization and efficiency of *men* as well as of machines; an engineer who regarded industrial relations from the viewpoint of a practical business man; and an engineer whose dominating purpose was to promote the Peace and prosperity of the whole world and to increase the stability and means for defence of his own country; but an engineer who did not permit his lofty conceptions of universal brotherhood and happiness to obstruct that practical habit of thought and course of action which are necessary if prolonged hostilities are to be avoided, and if material benefit is to be bestowed upon the majority of men.

But Fulton was also a *distinguished* member of the original family of American engineers. Fulton was an engineer of exceptional courage, foresight, and mechanical and business ability, which enabled him to achieve great success. As such, he was a Great Man, a Great American, and a Great Engineer.

To Fulton belongs the honor not only of having constructed the first commercially successful steamboat for purposes of commerce, but of having built the first steam war vessel in the history of the world. She was the DEMOLOGOS, afterward called FULTON THE FIRST. Her keel was laid on June 20, 1814, in this City; and she was launched October 29 in the sight of thousands of spectators. Difficulties in procuring labor and the untimely death of Fulton on February 24, 1815, caused serious delays in the completion of the DEMOLOGOS. On her first trial trip in June, 1815, the soundness of Fulton's views, and the fact that a heavy floating battery could be propelled by steam, were established. Her two subsequent trials further demonstrated her success, her speed exceeding Fulton's guarantee to the Government. Peace being declared, there was no opportunity to test the vessel in actual combat, and the DEMOLOGOS was sent to the Brooklyn Navy Yard for a receiving ship, remaining there until June 18, 1829, on which date she was blown up either by accident or design.

The DEMOLOGOS was a double-ended, twin-hulled floating battery of 2,475 tons, carrying twenty 32-pounder guns, protected by 4 feet 10 inches of solid timber. These guns were to fire red hot balls. The machinery was calculated for the addition of an engine to discharge an immense column of water, intended to be thrown upon the decks and all through the ports of an enemy. In addition to all this, two 100-pounder columbiads were to be suspended from each bow, so as to discharge a ball of that size into an enemy's ship, 10 or 12 feet below the water line. It is not surprising that she was, in her day, described as being "*the most formidable engine of warfare that human ingenuity has contrived.*" The DEMOLOGOS was driven by a single central paddle wheel; her speed was 4 1-2 miles per hour; and she was both handy and seaworthy.

The following extract from a Scotch newspaper is an amusing example of the exaggerative accounts of the DEMOLOGOS, which were scattered broadcast. "Her length," says the writer, "on deck is 300 feet; breadth 200 feet; thickness of sides 13 feet, of alternate oak plank and cork wood; carries 44 guns, 4 of which are 100-pounders; and further to annoy an enemy, attempting to board, can discharge 100 gals. of boiling water in a minute, and by mechanism brandishes 300 cutlasses with the utmost regularity over the gunwales; works also an equal number of heavy iron pikes of great length, darting them from her sides with prodigious force and withdrawing them every quarter of a minute."

As Americans we can all look upon the first steam war vessel of the world with especial pride, and we can note with gratification that the vessels of our Navy to-day are, ton for ton and gun for gun, equal to those of any Navy afloat. If it were possible for Fulton to have lived for such a length of time, he would share with us in our pride; and we can imagine what his thoughts and feelings would have been at the splendid achievements of the OREGON.

There is living in New York to-day, a veritable veteran of the engineering profession, who as a boy saw the CLERMONT and the DEMOLOGOS, and who as a young man was the designer of the machinery of the Second War steamer of the United States, which was called FULTON THE SECOND. He was also the first engineer officer to be appointed in our Navy, and, later, he had the honor to become Engineer-in-Chief. To bridge such a period of History and to have played so important a part in it, is a privilege which comes to very few of us—but this privilege has come, as most of you know, without the telling, to Mr. Charles H. Haswell.

When reviewing the world's progress during the Nineteenth Century, we see that its grandest glory was gained by the *Steam Engine*, which has been styled its "Hero." The work of the stationary steam engine is epitomized in the phrase "*increased production;*" and the work of the locomotive steam engine on both land and sea is epitomized in the phrase "*increased distribution.*"

With these two phrases, the history of the material progress of the world may be said to be written.

The Steam Engine sung, in mighty deeds, the "Song O' Steam," throughout the Nineteenth Century, and at its close a vigorous poet caught up the dominant note of his age and, in vivid tones, set it to swelling and echoing to every corner of the earth.

The duty and destiny of America for the greater part of the Nineteenth Century was, as my hearers well know, that of internal expansion and development. The practical establishment of Steam Navigation by Fulton and its further improvement by the many Engineers who followed him—chief among whom in this Country was the great Robert L. Stevens, son of the famous Colonel John Stevens—played a vital part in this development. In the true destiny of the Country the side-wheel steamer found its true destiny; and throughout the past Century nobly met the needs of the Nation. On our deep sounds and reaching rivers there ply to-day numberless descendants of the CLERMONT—highly efficient and finely equipped—carrying swiftly to their destination both passengers and the burdens of commerce.

To-day the duty and destiny of the Nation is for a greater expansion and development; and the hopes, thoughts and interests of the people are turning toward far away Islands—*and toward the commerce of the seas.* If the American Inventor or Engineer does his part in the solution of the problems of the present Century as well as Fulton did his part in the solution of the problems of the past Century,—there need be no fear for the continued growth and prosperity of the Nation.

We see in Fulton all the qualities that make for the success of America—character, courage, perseverance, energy, enterprise and skill. We see in Fulton the true American spirit—a high, hopeful, progressive, liberty-loving and practical spirit.

Fulton was high minded and generous; and he was true to his friends in their adversity. He was noted for his amiable disposition and genial hospitality. It was said of him that he was "a gentleman in mind and manners." He was a man of refined tastes, and, besides his active efforts during the most of his lifetime for the promotion of the Mechanic Arts, it was his endeavor to foster a love for the Fine Arts, and failing in his project to establish an Art Gallery in America, he bequeathed to our Government at his death, two of West's masterpieces which were his most prized and valued possessions.

In closing, it is fitting to reiterate that as an Inventor, Fulton earned the highest crown that he could earn—*success*, and his name should be honored by all inventors. As an Engineer, Fulton did all that he could do to promote the welfare of the world, and his name should be honored by all engineers. As an American, Fulton was a true type and gained glory for his country, and his name should be honored by all Americans.

As such, ROBERT FULTON was a Great Engineer, a Great American and a Great Man; his memory should be respected the world over, and his name ever revered by our people.

ADDRESS OF COMMODORE B. F. ISHERWOOD, UNITED STATES NAVY.

On the present occasion, the character, the career, and the achievements of Robert Fulton, will be eloquently described, and in sufficient detail, by others, who will do ample justice to his name and fame. The extent and precision of his mental view, his sagacity and perseverance, and the importance of the crowning success of his life, will be treated by them with the elaboration due to his genius. He is one of the few who can, in all respects, be held up not only for admiration but also for imitation, as uniting in himself those qualities of heart, and those powers of head, which, in all ages and in every clime have been held to constitute the ideal of manhood.

But quite apart from his individuality, and quite apart from any estimate of the intellectual value of his invention, there must be considered the immense service he rendered to mankind by accomplishing the commercially successful introduction of steam navigation. Others, preceding him, may have entertained in a vague and impracticable way the idea of propelling vessels by steam power; but there remained for him alone the splendid triumph of practical success, of clear definite foresight, of distinct knowledge of details, and of proper adaptation of means to the end. There is an immense difference between dreaming and realizing dreams, between the incomplete and hazy conception of an idea, and its tangible application for the production of a clearly defined material purpose, between the grasp and power of real genius aided by practical knowledge, and the weak, cloudy aspirations of uninformed imagination. To the world at large, the importance of the one is immense, and the value of the other is nothing. Such is the difference between the state of the subject of steam navigation as it came to Fulton and as it left his hands.

In conformity with a universal law of natural development, the invention of the steamboat could not have been made much earlier than it was. Obviously, the steam engine had to be previously not only invented, but it had to undergo successive modifications of form and details before it could be used as a motor in navigation. Further, the tools and processes for the manufacture of the steam engine had to be invented as their necessity became apparent by experience during the successive improvements of the latter. If, during the earlier period referred to, complete working drawings could have been made for a modern steamer—hull and machinery—the execution of the work would have been impossible: the low state of the contemporary industrial arts would have precluded even an attempt. Newcomen, Watt, and their immediate successors in steam engineering had necessarily to precede Fulton. The success of the latter was only possible after the success of the former. A Boulton and Watt steam engine manufactured in England caused the success of the CLERMONT in America. Mechanical science and art in their various departments have always had to advance, and will always have to advance abreast, simultaneously as it were, and no great development can be effected in any one particular department without an equal development, *pari passu*, in all the others; and this statement remains as incontrovertible at the present time as during the long history of the progress of the human race. In the case of the steamboat, there were peculiar difficulties to be overcome. The boat had to carry the machinery and fuel necessary to propel it, which, in connection with the weight of the hull, left so little of space and displacement commercially available, that only the prescience of real genius could foresee a possible success. The difficulties in question remain to the present hour, and if they have been overcome to a degree never hoped for by Fulton in his wildest dreams, the success is due to the steady advance of the industrial arts and processes, which have given to the Naval Architect and to the Mechanical Engineer tools and material whose invention required in their turn genius and knowledge as great as that which in the primitive age of steam engineering produced the steamboat of Fulton. Fulton's problem was entirely different from the use of steam as a motor on land, and his great merit was that he understood this difference and successfully coped with its difficulties.

These observations do not in the least detract from Fulton's deservedly high reputation. The greatest inventions are but the crests of mighty waves of slowly accumulating knowledge, and depend for final success on the conjoint influence of a vast variety of causes impossible for any intelligence to anticipate. The invention must not only be right in itself, but it must appear at the right time and under the right circumstances.

In these respects, Fulton was singularly fortunate. The talents of Newcomen, Smeaton, Watt, and their immediate successors, had produced the necessary motor—the steam engine—in England, and Nature, in America, had produced the noble rivers and bays whose broad surfaces of placid water furnished the proper locale for the steamboat in its primitive state of rude construction.

At this period the steamboat could not have been introduced with commercial success in any other country than America. For ocean navigation it was at that time entirely unfit, and had not America presented the proper conditions for its appearance in its state, at that time its advent would have been postponed to a much later period. But, evidently, sooner or later, had Fulton never existed, the steamboat would have been produced. That a steam engine would not have been placed in the hull of a vessel for its propulsion, is unthinkable when the universal application of steam engines for the doing of all kinds of work under all kinds of conditions is considered. If the circumstances do not make the man, they, at least, permit him to appear; and that he prove himself equal to a great occasion is a great distinction in itself. Without Fulton, the steamboat would finally have been invented, but, as the first in the field, his name is justly and imperishably associated with it. His talents added wings to the car of time and expedited the slow developments of nature; he forced the appearance at an earlier period, and greatly to the benefit of mankind, of what would certainly have appeared much later by the more sluggish operations of feebler causes.

The steamboat, therefore, is peculiarly American, and be the modifications what they may which the advance of the industrial arts, and the change in commercial conditions, have made in it, the steamboat of Fulton remains forever the type, and his name will be associated with it as long as vessels are propelled by steam.

From the primitive, small, and rudely built wooden steamboat of Fulton, capable of slowly navigating only smooth water for short distances, to the huge and elaborately constructed steel transoceanic steamers navigating the stormiest seas at comparatively enormous speed, carrying the people and the products of one continent to another, increasing the wealth and happiness of all, and spreading civilization, art, science, and intelligence throughout the world, with hope at the helm and at the prow, the holy group of peace, good will, and mercy, the gap seems great indeed; but it has been filled by successive generations of Naval Architects and Engineers, elaborating and perfecting the ideas of Fulton. Where Nature seemed to intend eternal separation by the interpositions of oceans, Art has made union practicable, so that the blending into one harmonious mass, of different and discordant races by means of the easy, cheap and rapid transportation furnished by the steamship, seems no longer to be an iridescent dream but a possible reality. If the greatness of an invention be measured by the benefits it confers upon the world, the steamboat of Fulton must be placed in the first class of the catalogue.

We have met to erect a memorial to Fulton, and to show our appreciation of the man, his genius, and his services. The event honors us, he does not need our effort. Wherever a steamer floats, there is a monument to Robert Fulton.

EULOGY ON ROBERT FULTON, ARTIST, ENGINEER, INVENTOR AND PATRIOT.

By Robert H. Thurston.

"Let us pass in review the great founders of modern science and then creators of industry, the Keplers and the Fultons, and we shall be struck by the idealistic and even utopian tendency peculiar to them. They are in their way dreamers, artists, poets, controlled by experience."

Quotation by General Walker from the French.

Members of the A. S. M. E. and Friends: The genius of Robert Fulton, in its highest and most impressive aspect has seldom been fully recognized and appreciated, even by those who have most admired the man; the moral and the spiritual side of his character has never received adequate recognition and exposition by any one of his most enthusiastic memorialists. His versatile and active mind and his skilful hands were always engaged in some useful and worthy task; but it is not his admirable portraiture, nor his inventions nor even his most famous deeds that constitute his highest claim to our admiration and to eulogy. He was an artist but his paintings were eclipsed by those of his friend and helper Benjamin West; his fame was overshadowed by that of the greater artistic genius. He was an inventor; but his inventions have been almost forgotten and his fame, in the popular mind, at least, is based upon his work in the utilization of the inventions of others or previously anticipated devices. He led the way to inconceivable gains to his country and to the world; yet his highest aspirations for his country and the world have never been realized, and his ambition, where most earnest and tense, has never seen fruition. Generally supposed to have been a great inventor, his inventions have sunk into oblivion; popularly considered only an inventor, his talent as artist is forgotten, while the devices upon which his fame as inventor has actually arisen were neither original nor novel. A talented artist, he is unknown as such; a skilful engineer, his engineering work, mainly on canals and bridges, is forgotten; a prolific inventor, we hear little of his most important inventions and much of his assumed, but erroneously assumed, original work. A patriot and inspired with the highest and noblest patriotism, his aspiration to compel, by his inventions, a cessation of, at least, naval wars and "to assure to all men of all nations the freedom of the seas" has never been understood, or perhaps even heard of, by the mass of his fellow-citizens or by later generations. Fulton's fame is not only deserved; it is worthy of vastly broader and higher recognition than it has ever gained or is ever likely to receive; but it has a basis, rightfully, in quite other and higher considerations than those popularly assumed.

It is to this inventor whose inventions are unknown, this artist whose paintings are never recognized, this engineer whose achievements in his profession, whose public works, have passed into oblivion, this patriot whose labors and aspirations for the highest interests of the country and for the unity of the nations are known to few and comprehended by fewer of his countrymen, that we are here now to render tribute.

Robert Fulton inaugurated the application of steam power to the purposes of marine transportation, established permanently steam navigation in all waters, "reduced to practice" a system of applied energetics to which inventors of all ages and of all lands contributed; leaving to this great American engineer the privilege of combining all existing knowledge and earlier invention into one practicable and successful construction.

Hero of Alexandria led the way with a steam-turbine and a steam-fountain; the Marquis of Worcester applied to useful purposes the toy of the Greek; Captain Savery perfected the steam-fountain of that noble inventor; Newcomen and Calley displaced the steam-fountain by the modern train of mechanism which is properly called an engine; Watt improved the steam-engine, crude and wasteful, in its first form, by adding the essential features of the steam-engine of the nineteenth century, giving it its condenser, its regulator, its expansion-gear and its double-acting form; making it capable of turning a shaft, of driving a mill, of impelling the railway train or a steamboat.

Long before Fulton and long before Watt the steamboat had been conceived by the earlier inventors or dreamers. The ancients had used the paddle-wheel; Homer had dreamed of the marvellous ship "self-moved, instinct with mind."

> "We use nor Helm nor Helmsman. Our tall ships
> Have Souls, and plow with Reason up the deeps;
> All cities, countries know, and where they list,
> Through billows glide, veiled in obscuring Mist;
> Nor fear they Rocks, nor Dangers on the way."
>
> (Ogilby's Odyssey.)

Roger Bacon had predicted the use of steam in navigation 500 years before Fulton: "Instruments may be made by which the largest ships, with only one man guiding them, will be carried with greater velocity than if they were full of sailors." Jonathan Hulls patented his steamboat in 1637 and is said to have reduced the invention to practice. Papin, famous man of science, built his awkward steamboat in 1707; Fulton made his successful trip from New York to Albany in 1807, after Rumsey and Fitch and Stevens and others had made working and mechanically successful steamboats.

But while Fulton did not invent the steamboat nor any one detail of the construction of hull or machinery of his CLERMONT he did what no man had previously accomplished: he inaugurated, with the inventions of other great mechanics, the modern system of steam navigation. He established commercially and permanently successful steam transportation lines on the Hudson River and on Long Island Sound; he introduced the steam ferry-boat and established Fulton Ferry and other steam ferries about New York; he organized the steamboat lines on the Connecticut and on Long Island Sound and led the way in confirmation of the prediction, made, in 1798, by "poor John Fitch," who, finding a tomb on the banks of the Ohio, desired that he might lie "where the song of the boatman would enliven the stillness of his resting-place and the music of the steam-engine soothe his spirit."

Fulton first applied steam propulsion to a naval vessel of, for the time, great magnitude, and powerful for both offence and defence, and built, as his last offering to his country, the "Fulton the First." He led the way toward the construction of the modern merchant and naval fleets of the world and made commerce between nations and rapid communication between the ends of the earth independently of the winds a realized dream.

His greatest aspiration, the absolute freedom of the seas to all nations and to all men, has been nearly accomplished, though not by Fulton's plan of driving all warring fleets from the ocean by peril of submarine foes, but rather by the gradual recognition of the rights of neutrals and non-combatants; while the perfection of his idea of a submarine craft, such as he actually and successfully built and operated a century ago, was left to the Hollands of our own time; who are rendering concrete the fancy of Jules Verne and the dream of Captain Nemo.

A rapid outline of the life and work of this still unappreciated artist, inventor, engineer and patriot may fitly preface our feeble eulogy of the still greater man:

Robert Fulton was a Pennsylvanian, born on the banks of the Conestoga, in 1765, and, later, a friend of Benjamin West, the artist, of William Henry, the would-be inventor of steamboats, of Thomas Paine, the man of "Common Sense," and the revolutionary patriot, and of Joel Barlow and Chancellor Livingston, great American statesman. West encouraged the boy to cultivate his talent as artist and draughtsman; Henry interested him in the construction of steamboats; Paine inculcated a noble patriotism and Barlow and Livingston aided the young inventor in the perfection of his designs and the utilization of legislative action in their introduction. At the close of the eighteenth and the beginning of the nineteenth centuries, Fulton was in England and France seeking the patronage of the governments of Great Britain and France for his inventions of various improvements in the apparatus of canals, in submarine navigation and in the construction of steamboats. He published a work on canals, in which he described his improvements, in both England and France. Copies may still be occasionally found by the antiquarian, both in English and in French. While in France, he built a steamboat, in 1803, and finding the results of his first experiment promising, arranged for a repetition on a much larger scale when he should later return to the United States. He ultimately, succeeding more than satisfactorily, gave his life to the work of promoting steam navigation.

Fulton lost no opportunities to study the work of others, apparently. It is asserted by almost every mechanic experimenting at about this time in the same field of invention and construction, or by their friends, that Fulton visited and inspected the work of these inventors, and it is not infrequently claimed that he made use of their ideas and even, as one inventor of less success phrased it, "stole the invention." It can hardly be doubted that Fulton was intensely interested in the subject from boyhood or that he had unusual opportunities to become familiar with the contemporary work of the naval constructor and engineer. He was eighteen or nineteen years old when his friend and patron, William Miller, of Lancaster, Pennsylvania, was experimenting with a model steamboat on the Conestoga River and could hardly have failed to have been interested, and intelligently interested, in those experiments. He was between twenty and twenty-five when the work of John Fitch, who traversed thousands of miles and carried thousands of passengers on the Delaware between 1785 and 1792 or later. He was over thirty when Fitch placed his screw-propelled steamboat on Collect Pond in New York. James Rumsey exhibited his steamboat, with its hydraulic propeller, to Washington, 1786, and worked as earnestly as did Fitch, all through the last quarter of the eighteenth century, to introduce his particular form of steamboat, dying, finally, in London in 1793 while on this mission abroad. D'Auxiron, Jouffroy and others in France were engaged during this same period and earlier, in similar experiments in France; and Miller, Taylor and Symington were contemporaneously developing the steamboat in Great Britain. All this work was not simply publicly known but was widely advertised, with extravagant claims, often, of successful performance, and the whole civilized world was awake to the importance of the development of steam navigation. Morey's friends claim that Fulton saw his experiments at Oxford and the friends of the British mechanics assert that he utilized their ideas after a visit to study their experimental craft. All this may be entirely true and is not at all improbable; but it derogates nothing from the credit due the great pioneer in the reduction of the invention and its accessory devices to a permanent and universal practice. Fulton was in no degree dependent upon any other engineer or constructor for his success. He simply took a Boulton and Watt engine to America and set it up in a New York builder's hull and went his way, astonishing the world and setting a fashion that has never since gone out. His triumph was that of science and professional learning over amateurs and untaught mechanics. Fulton was not simply a mechanic; he was a scientific man; not merely an inventor, but a man of science perfecting inventions by scientific methods, systematically investigating and basing his work upon research and logical deduction. He first experimented, then reduced his observations to form and sequence, then deduced from his researches the laws controlling the subject and finally produced his idea, crystallized in metal, of exact form and proportion and capable of doing the work proposed in precisely the best practicable manner.

He first made an experimental investigation of the laws of fluid-resistance and ship-propulsion, conducting his researches precisely as, to-day, with our improved method and apparatus, our naval constructors and engineers determine the resistances and the engine-power required in similar cases in modern construction. He next reduced the resultant data to tabular form, studied the relations of magnitudes of forces and of speeds for floating bodies of different sizes and proportions, discovered the laws of fluid-resistance in this manner, and finally applied them in the computation of the necessary horse power of an engine intended to drive a steamboat at a stated speed. He compiled the work of others, where practicable, and, among his papers, found at his death carefully filed, were drawings of his apparatus for experiment and a "Table of the Resistance of Bodies moved through Water; taken from Experiments made in England by a Society for Improving Naval Architecture, between the Years 1793 and 1798." The original of this drawing was filed in the "Office of the Clerk of the New York District, making a part of a Demonstration of the Patent granted to Robert Fulton, Esqre., on the 11th Day of February, 1809."

Fulton was thus able to do what no previous constructor, so far as we know, had done—to compute with considerable accuracy the size, power and weight of his propelling engine and accessories. He was thus prepared to follow the method of the scientific professional, as distinguished from that of the uninformed inventor, and he was among the first of those professional engineers who pioneered the way to the displacement of amateur "invention" by scientific design and led to the production of mechanism precisely adapted to a very exactly defined purpose, not by a process of guesswork, but by first a deliberate and logical process of definition of the problem and, then, of its solution; much as the modern strategist, in war, proceeds to the reduction of a known defensive position. In mechanics, as in war, there is always a correct, a scientific and a certain method of attaining a result, once the elements of the problem are precisely stated qualitatively and quantitatively. Fulton's first attempts were thus successful and his first steamboats performed precisely as he intended that they should.

He was neither engine-designer nor hull-constructor; he was a naval architect, adapting a well-known motor to a long recognized purpose and he succeeded through the fact that he first made himself familiar with scientific principles and with the contemporary practice in both engine-building and ship-propulsion and was thus enabled to effect a combination of motor and vessel in a satisfactory manner, at the very start.

In the latter part of the eighteenth century, Fulton was in England and in France engaged in the endeavor to promote his inventions and devices, as he said, "for insuring the freedom of the seas to all men." He constructed submarine torpedo-boats and made them vastly more safe in use and more manageable, and more dangerous to an enemy, than any since constructed until our own day. He operated them in the French harbors until the anxiety of all other nations was aroused lest the new weapon should be employed against them. This submarine navigation and its apparatus involved more real invention than any work which Fulton accomplished with the steamboat and entitles him to more credit, perhaps, as an inventor, than any other achievement of his life; but the practical outcome of his steamboat construction has caused the almost complete eclipse of what would probably otherwise have proved to be the source of his fame. Of his work on the canals and his various inventions in connection therewith, we hear practically nothing, notwithstanding his careful descriptions and the publication of his books on the subject. The permanent introduction of the steamboat proved to be a feat which, in glory, outshone all.

Fulton's first steamboat was built on the Seine, with the aid of Chancellor Livingston and Joel Barlow, then at the court of France in official capacities. It was launched in the spring of 1803. Although Fulton's computation of the size and power of the steam-engine and boiler employed were correct, it proved that the builders were less fortunate in their design of the hull. The craft went to the bottom before it could be given a trial. But it was promptly raised and strengthened, and, in August, 1803, a committee of the French National Academy, including the famous elder Carnot, took part in the trial of the first really successful experiment ever made in this direction in that country. The boat made four and a half miles an hour. The steam-boiler used in this craft was devised by Barlow and was a water-tube boiler of a very practical type. It is still preserved in the Conservatoire des Arts et Metiers in Paris. Barlow had patented it

1793 as a steamboat boiler, as he expressly states, and his ect in the adoption of this type was, as he further says, "the centration of the largest amount of heating surface possible hin a limited volume and weight"—primarily important deerata in steam navigation.

The results of this experiment were of world-wide importance. e French government declined to aid the inventors and pro-ters of the scheme notwithstanding the favorable reports of entific men and other witnesses of the trial-trip and Fulton d Livingston turned their faces toward America.

Livingston secured the extension of a grant, previously allowed the State of New York, of a monopoly of the navigation of e Hudson River to any successful constructor of a steamboat those waters, and Fulton ordered, in 1804, from the firm of ulton & Watt, a Watt-engine of twenty-four inches diameter steam cylinder and four feet stroke of piston—a rather large achine for the time. His first boat had been of moderate size, good proportions and shape—66 feet long, 8 feet beam and light draught—and thus obtained a new point of departure in s computations of size and power of motor and corroborated s previously asserted opinion that paddle-wheels were the best rm of propelling instrument known at a time when Rumsey as trying hydraulic propulsion, Fitch and the French inventors ere proposing or using "chaplets" of paddles and the screw. Livingston's grant and Fulton's steamboat together made eam navigation possible and even a certainty, and a practical nd financial success for all time.

Fulton went to England, 1804-6, and saw his engine well along ward completion under the eye of Watt, sent over his specifica-ions to Charles Brown, the East River shipbuilder of the day, nd then, in October, 1806, sailed for home, arriving in New ork, December 13, and there commenced the supervision of is new work.

The hull was now that of a comparatively large craft—133 eet long, 18 feet beam and 9 feet depth—of good proportions or the intended speed, seven beams in length and a depth one alf the beam; giving good evidence of the familiarity of Fulton with the science of naval architecture of the time and illustrating gain our proposition that his work was that of the skilled engineer and naval constructor, of the man of science and the professional engineer, rather than that of the empiric.

The trial trip was made in August and was simply the first of a never interrupted series and the beginning of a traffic which has ever since grown and has, each year, more and more advantaged the nation. The CLERMONT, named after the Livingston manor, was the progenitor of all modern steam fleets.*

The voyage of the CLERMONT to Albany was attended by some ludicrous incidents, which found their counterparts wherever, subsequently, steamers were for the first time introduced. Mr. Colden, the biographer of Fulton, says that she was described, by persons who had seen her passing by night, "as a monster moving on the waters, defying wind and tide, and breathing flames and smoke."

This first steamboat used dry pine wood for fuel, and the flames rose to a considerable distance above the smoke-pipe. When the fires were disturbed, mingled smoke and sparks would rise high in the air. "This uncommon light," says Colden, "first attracted the attention of the crews of other vessels. Notwithstanding the wind and tide were averse to its approach, they saw with astonishment that it was rapidly coming toward them; and when it came so near that the noise of the machinery and paddles was heard, the crews (if what was said in the newspapers of the time be true), in some instances, shrank beneath their decks from the terrific sight, and left their vessels to go on shore; while others prostrated themselves, and besought Providence to protect them from the approach of the horrible monster which was marching on the tides, and lighting its path by the fires which it vomited."

---

* John Stevens was Fulton's greatest contemporary and rival in the endeavor to place steam navigation upon a satisfactory and permanent commercial basis. John Stevens, also a statesman, an inventor and a famous engineer, unquestionably outranking Fulton in some respects, and, later in his own person and in the persons of his immediate relatives, successful in the construction and operation of more original forms and details of motive machinery, very nearly gained the prize. This great engineer and pioneer in both marine and land transportation by steam-power, had built screw-boats in 1804–5 and the *Phoenix*, a paddle steamer, was completed just too late to even compete with Fulton and was sent around into the Delaware; the monopoly secured by Fulton and Livingston on the Hudson ruling all other steam-propelled craft off of that great estuary. Years afterward, when that monopoly was declared by the courts illegal, on the ground that the General Government only could control tide-waters, the Stevens, father and sons and nephew, and their successors, proved themselves entitled to a place in our modern Hall of Fame beside Fitch and Fulton, and carried on the development of the American river steamboat to a piont of great perfection. But now Fulton had secured his opportunity; and well did he and his coadjutors profit by it.

n the CLERMONT, Fulton used several of the now charac-stic features of the American river steamboat, and subse-ntly introduced others. His most important and creditable ·k, aside from that of the introduction of the steamboat into ry-day use, was the experimental determination of the mag-ude and the laws of ship-resistance, and the systematic pro-tioning of vessel and machinery to the work to be done by m.*

The success of the CLERMONT on the trial-trip was such that lton soon after advertised the vessel as a regular passenger-it between New York and Albany.†

During the next winter the CLERMONT was repaired and en-ged, and in the summer of 1808 was again on the route to bany; and, meantime, two new steamboats—the RARITAN and CAR OF NEPTUNE—had been built by Fulton. In the year 11 he built the PARAGON.

The construction of a line of steamers for the Hudson River omptly followed the success of the CLERMONT and immediately erward the waters of Long Island Sound and the Connecti-t and adjacent rivers and estuaries found place for many steam-ats. The great rivers of the West now began to take on

---

* History of the growth of the Steam-Engine.—Thurston.

† A newspaper-slip in the scrap-book of the author has the following:

'The traveller of to-day, as he goes on board the great steamboats St. John Drew, can scarcely imagine the difference between such floating palaces and wee-bit punts on which our fathers were wafted 60 years ago. We may, how-r, get some idea of the sort of thing then in use by a perusal of the steamboat nouncements of that time, two of which are as follows:

["*Copy of an Advertisement taken from the Albany Gazette, dated September*, 1807.]

"The North River Steamboat will leave Pauler's Hook Ferry [now Jersey City] on Friday, the of September, at 9 in the morning, and arrive at Albany on Saturday, at 9 in the afternoon. visions, good berths, and accommodations are provided.

"The charge to each passenger is as follows:

"To Newburg	dols. 3,	time 14 hours.
" Poughkeepsie	" 4,	" 17 "
" Esopus	" 5,	" 20 "
" Hudson	" 5½,	" 30 "
" Albany	" 7,	" 36 "

"For places, apply to William Vandervoort, No. 48 Courtlandt Street, on the corner of Green-h Street.

"*September* 2, 1807.

["*Extract from the New York Evening Post, dated October* 2, 1807.]

"Mr. Fulton's new-invented *Steamboat*, which is fitted up in a neat style for passengers, and ntended to run from New York to Albany as a Packet, left here this morning with 90 passen-s, against a strong headwind. Notwithstanding which, it was judged she moved through the ters at the rate of six miles an hour."

the aspect of which "poor John Fitch" had dreamed a generation earlier and New York and Albany, New Jersey and Massachusetts, Pittsburg, and New Orleans were united by lines of steam vessels, strongest of all bonds in the bringing together and the holding together of peoples. The construction of steam ferryboats followed and the Fulton and the Jersey City ferries from New York to either adjacent shore were inaugurated in 1812 and 1813, the first of all steam-ferries.

With the outbreak of the war of 1812 with Great Britain, Fulton set himself to work upon the plans of a steam man-of-war and submitted them to a commission appointed by the Government, consisting of the greatest captains of the time, including Decatur, Perry, Paul Jones, and Evans. His plans contemplated the building of what was for the time a very large vessel—a double hull, with the paddle wheel between, protected from shot, the length to be 156 feet, the breadth of beam over all 56 feet, and the depth 20, measuring 2,475 tons; which was, in those days thought an enormous size. The ship was to be given a very heavy battery, to have a speed of four miles an hour and to be especially constructed for the defence of New York and the harbor. Fulton proposed that some of the guns should be arranged to discharge their shot below the water-line and others to throw red-hot shot into the enemy's upper works. The cost was to be $320,000—about ten per cent. of that of the average ironclad of to-day, while the costliest ship of the modern fleet would in cost balance a fleet of twenty of Fulton's first steam war vessels. It was named the "Fulton the First."

The contract was authorized, March, 1814, and the keel laid the following June; but the ship was not ready for her trial-trip until May, 1815, and had no part in the war; although the moral effect of this world-wide famous vessel, at the time, was probably very considerable. The ship was propelled by an engine having a cylinder 48 inches in diameter and 5 feet stroke of piston, supplied with steam by a copper boiler 22 feet long, 12 feet wide and 8 feet high and turned a wheel 16 feet in diameter, 14 feet width of face and length of bucket and with a "dip" of 4 feet. The boiler was in one hull, the engine in the other. The sides at the battery-line were 4 feet 10 inches thick, and the bulwarks were musket-proof. The armament consisted of thirty 32-pounders and a submarine gun throwing a shot weighing 100 pounds at a depth of 10 feet below the water-line. On her trial-trip, in the month of July, she steamed from New York, at the ıttery, to Sandy Hook and back, 53 miles, in 8 hours and 20 inutes, light. In September, 1815, with all stores on board and ady for sea, she made a speed of five and a half miles an hour the bay.

But Fulton never saw the completion of this, his greatest ork. He died February 24, 1815. But his work was done ıd well done. We need only mourn his deprivation of the opportunity to see it in all its perfection and to receive from his llow-countrymen full recognition of their indebtedness to him ıd assurance of their respect and honor and love for their beneıctor.

As from the CLERMONT have sprung the merchant fleets of ıe world and out from that little craft have grown Campanias ıd Oceanics of our time; so, from the "Fulton the First," have ›me all the naval fleets, the "Oregon," and the "Olympias" ıd the "Brooklyns" of our own day. Steamboats had been ·en before Fulton laid down his first keel on the banks of the eine; but it is from Fulton's first successful steamboat that l fleets have been derived. Armored war-vessels had been uilt earlier; but it was from Fulton's steam frigate with its rotected sides and batteries that the contemporary ironclad was neally descended. In 1807 the "Clermont" was alone in the 'orld as a commercially successful steamboat operating upon a ;ated route; to-day, in place of the little 200-ton vessel of Fulon, we find steamships on every sea, monsters of thousands of ›ns, sometimes of twenty thousand tons displacement, carrying ıeir enormous freights and thousands of passengers across every ›a, to the farthest ports of every continent, to the furthest lands of the Pacific Ocean, the commerce of the world, exchangıg the products of every land and of every clime.

The sailing vessel with its costless power, is driven from the ›as by the costly yet more economical power of steam. In place f the thirty or, at most, fifty horse-power of the pioneer craft, s successors on the Hudson exert the power of a thousand and ıore and on the Long Island Sound of several thousands, and n the oceans, three, five and ten thousand horse-power ships are ommon, while the maximum, now twenty and thirty, will soon e fifty thousand horse-power, in a ship approximating a thousand eet in length and thirty thousand or more tons displaceıent. For the five miles an hour of the CLERMONT is now substiuted the twenty miles of the "Mary Powell," and her grand uccessors, the "Puritan," the "Pilgrim," and the "Priscilla," in smooth water, and the twenty-five and thirty miles achieved by the great "ocean greyhounds" and the modern naval "cruisers" and torpedo-boats. with an occasional spurt up to forty miles, as measured on land, and by the land measure.

Fulton sought to insure the freedom of the seas to all men and all nations by his inventions and improvements in naval and submarine instruments of warfare, giving the weakest nations such power as should compel the respect of the strongest and making all equal. His plans have been adopted throughout the world and a century of further improvement has left his task still unaccomplished; but his spirit is still existent and is pervading the world more and more, as it gains in intelligence and in morals, and the permanence of peace is better assured and war is far more dreaded and more carefully avoided than ever before. The spirit of peace, of justice and of fair play, of humanity between man and man, is growing as never before. The seed so well sowed by Fulton has germinated, even if the fruit is not yet ripe, and the use of the sword, if necessary, in the prevention of war and the combination of the strong to control the ambitions and impositions of the strongest are insuring peace, while the progressing civilization of the world is steadily bringing us toward a period of universal peace and of international courts for settlement of differences. A century has done much to prove the nobleness and the wisdom of Robert Fulton.

Robert Fulton died at the age of fifty years, in the prime of life and at the maximum of his mental and physical powers. He at the time was still serving the United States as naval constructor and contractor, and the government was in debt to him $100,000 for moneys advanced by him and his associates on work in hand. The work was completed; but, as occurred in the case of Ericsson, another great benefactor of the country, a half century later, these claims were never fully satisfied.

The New York State Legislature, then in session, paid him public honors such as were never before tendered any private individual; his funeral was attended by an immense concourse of his fellow-citizens and his grave, here at Trinity Church, about which we to-day congregate, and at which we now erect a memorial, was surrounded by national and State officials, by the magistracy of the metropolis, by its municipal council, a number of associations and many private citizens. As the procession moved toward the grave, minute guns were fired from the steam-frigate "Fulton the First" and the then fortified "Battery." The respect and esteem of the Nation were manifest. Yet his tomb remained, until to-day, unmarked!

And Robert Fulton well deserved that respect and esteem; he had well earned it by his statecraft as well as by his inventive powers, by his business ability as well as by his foresight and scientific attainments, by his genius, skill, patriotism and good works. Could he now return to the scenes of his labors and witness the outcome of his work, we may feel well assured that he would be more than satisfied and he would be convinced that his ambition and his hopes and his anticipations for his country, and his great plans of promotion of the best interests of the world, had been fully justified and are now more than realized, so far as the solution of that great problem in engineering is concerned; while his grander problem in statecraft has made a progress that few would have accepted a century ago. Steam navigation is now perfected far beyond his conceptions and the freedom of the seas is more complete than he could then have dreamed possible. Even his system of under-water navigation and warfare has come to be recognized as a practicable line of development and the day of warring fleets is waning and that of equality among nations is dawning.

"Peace on earth, good-will toward man," is still to come; but it is to Fulton that we are to attribute such progress in this direction as has been made, very largely, by the facilitation of intercommunication, and his has been a missionary work among all nations and all peoples. As the committee representing us in the preparation of this memorial, and to whom we owe cordial thanks therefor, has said, his was "an epoch-making work," and we are most fortunate in living in the earliest period of that epoch which he thus created and we, more than any later generation, owe him highest honor and gratitude; for his work has given us the greatest gain.

This memorial stands for our expression of that respect and appreciation.

To the Inventor, the Statesman, the Patriot, we raise this our monument. To the Man, the Engineer, the indomitable Builder of the World's Fleets, to the Founder of modern civilization, in large measure, we render honor on this occasion.

May the name of Robert Fulton endure forever and may all coming generations give him praise!

BIBLIOGRAPHY.

Memoir of Robert Fulton, by Cadwalader Colden, N. Y.; Kirk & Mercein; 1817.
Life of Robert Fulton, by J. F. Reigart, Phila.; C. S. Henderson & Co.; 1856.
History of the Growth of the Steam-Engine, by R. H. Thurston, N. Y.; Appleton Co.
Life of Robert Fulton, R. H. Thurston, Dodd, Mead & Co. (Makers of America).
Life of Robert Fulton, T. W. Knox, N. Y.; G. P. Putnam's Sons; 1890.

ADDRESS AT THE UNVEILING OF A MEMORIAL IN TRINITY CHURCH YARD TO ROBERT FULTON. ERECTED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. DELIVERED BY HIS GRANDSON, THE REV. ROBERT FULTON CRARY, D.D., RECTOR OF THE CHURCH OF THE HOLY COMFORTER, POUGHKEEPSIE, N. Y., IN TRINITY CHURCH, NEW YORK CITY, DECEMBER 5th, 1901.

The age in which we live is charged with forgetfulness. The turmoil of traffic, the fusion of our many financial forces, the complexity of our national life which now touches that of every other government under heaven; the trend of travel, the agitation of our aggregated activities; all these tend to produce in us as a people the spirit of nervous energy; the changing features upon the mobile face of our country of unremitting unrest.

We have had little time for lingering over past accomplishments. The stern future of unproduced achievement has beckoned the active minds of our thinking men to new fulfilment.

The nineteenth century, now asleep with by-gone history! What changes hath it wrought! Yet who can say what greater fashioning facts await the twentieth century, the threshold of which we have, with fine courage, and good hope, recently passed. God has blessed us, as a nation, with the dauntless courage of invention, with the prophetic vision of future possibilities, with the adventurous spirit of exploration, which dares to try new methods;

which hopes to win new victories; which ventures to uplift old standards, or to exalt those which are more ideal, when wisdom deems them best.

The artist, who has the radiant vision of his Masterpiece within his inspired mind, does not glory in the first sketches which proved his ability. He dauntlessly works on under the flame of genius toward the greater perfection. The musician who hears within his soul the unwritten notes of a heavenly melody, does not dwell upon the early exercises of his composition, even though they won for him his master's praise; he tunes his being day by day to listen to the low whispered harmony of a new song of songs.

The sculptor, who sees within a block of uncut marble a later winged victory, will not long gaze upon the early product of his active chisel, but will arise to new effort, that a wistful world may gain fresh inspiration. So has our nation pressed onward, seeing each day a brighter vision of her exalted place among the peoples of the earth; hearing each day a clearer song of freedom for her thiusands of trustful children; realizing more and more fully her power to release the radiant figure of a new victory for the body, soul and spirit of the united commonwealth of humanity, who yield to her their obedience, and who follow her guiding power.

What wonder then that in pressing forward in the turmoil of tense activity, we have sometimes paid scant honor to the former toilers in the first fields of our fair fatherland; men who have "hazarded their lives for the faith;" the faith that fashioned a new fabric to clothe our thought; and followed the flicker of a new prophecy. Men who spent their substance and toiled to demonstrate a new theory, or to demolish an old foundation, strong with the daring enterprise of the hope that was in them. "We touch and go, and sip the foam of many lives," says Emerson, yet sometimes, thank God, as in this event which to-day calls us together, we touch, and sip, and then drink deep of a life which has in it the strength of sacrificial wine, the vigor of an inspiration wrung from the wine-press of toil and sweetened with the nectar of human unselfishness. The foam vanishes from the glass, but the wine endures, and will endure unto the end of time, when the One Man above all His human brethren shall say at his own wedding to the Master of the Feast, "Thou hast kept the good wine until now."

To-day we are met together, my dear friends, for a practical refutal of entire forgetfulness, for the witness of a substantial proof that the memory of Robert Fulton is alive in his country, that his brother craftsmen, the American Society of Mechanical Engineers, appreciate his accomplishment and hold him in high honor.

You are, I doubt not, familiar with the story of his life. He needs not, nor would he, in his modesty have chosen his grandson to speak his praise. Other lips than mine have told that which history repeats, of the early struggle, and the ultimate success.

His parents came to Pennsylvania from Ireland early in the eighteenth century, and there is a strong probability that his father was a descendant of the Rev. Dr. Fulton, a Church of England clergyman, who in 1614 was chaplain to Lady Arabella Stuart. The line of connection has not been completely secured, yet interesting papers in our possession, taken from the second volume of the Clarendon Gallery give the historical statement as follows: "In the reign of James the first the Lady Arabella Stuart, first cousin of the King, was imprisoned in the Tower of London for having assisted William Seymour, afterward First Marquis of Hertford, to escape to France. During her captivity the Lady Arabella petitioned the King to allow her spiritual consolation; and on the 6th of September, 1614, a minute was drafted at the King's command, by the Privy Council to Sir William Wead, the Governor of the Tower, directing and commanding the Rev. Dr. Fulton to visit and console her from time to time.

The motto still used by the foreign branch of the family and by Sir Forrest Fulton, the present Recorder of the City of London, is, "In strength, and virtue;" and the name Fulton, is of Saxon origin, meaning a full town, a crowded village. The members of this clan, or village, proceeded northward at the time of the Norman conquest to avoid the invaders; the name is found in Ayrshire, Scotland, as early as 1296. Attached to Parliamentary Roll acknowledging Edward I as King Paramount.

William Fulton, the son of the Rev. Dr. Fulton, the Chaplain at the Tower, emigrated to Ireland in 1612.

During the reign of Elizabeth the Irish had been universally engaged in rebellion, and in 1611, the Province of Ulster having fallen to the crown by the attainder of the rebels, a company was established in London for planting new colonies in that fertile country. Tenants were brought over from England and Scotland, the Irish were removed from the hills and fastnesses, and by those means Ulster was converted from a wild and disorderly province to the best cultivated and most civilized in Ireland. One branch of the family of Fulton came over at this time from Ayrshire, and settled in and around Lisburn and Belfast. William Fulton, the son of the Rev. Dr. Fulton, settling in Kilkenny.

It was from Kilkenny, Ireland, that Robert Fulton's father emigrated to this country, and it is not therefore unreasonable to hope that the mystery of the few intervening generations may in time be reduced to facts of historic accuracy; certainly, the man had in his physical and mental equipment the vigor and vim of the Scottish hills as well as the wit and wisdom of the Irish mind; and it is, I trust, something more than a mere coincidence which Dr. Fulton, of New Zealand, cites. I quote from his personal letter: "It may be only a coincident but I have found many eminent civil and mechanical engineers of the name of Fulton all over the world. I know of one in Australia; a most eminent man in South Africa; another in Bristol; and one in New Zealand; two of my brothers were brought up as civil engineers, and one of them was a genius in railway construction."

I have quoted thus largely from the annals of the past, because these facts have, I think, hitherto been little known, and also because I feel that in them God has His lesson for us: He has often so endowed with special gift a chosen people, and Robert Fulton, though he strove alone and knew not those others of his name who shared his taste, was nevertheless not alone; for he in America, and they of far kinship, and in divers distant lands, and time, worked with their talent in likeness to his toil.

Robert Fulton was a patriot. Read his life, if you will, and see how amid the splendors of the old world, his heart, full of the fire of his new invention, yearned for America. He gave his best to his own country. In the concluding remarks of his paper on "Submarine Navigation and Attack," delivered in London in 1806, now in possession of the family, he says, "It has never been my intention to hide these inventions from the world on any consideration; on the contrary, it has been my intention to make them public as soon as consistent with strict justice to all with whom I am concerned; for myself, I have ever considered the interests of America's free commerce, the interest of mankind, the magnitude of the object in view and the national reputation connected with it, superior to all calculations of a pecuniary kind;" and again in another folio containing notes on submarine vessels, drawn June 12th to 20th, 1804, he says, "It is worthy the genius, and utmost care of the United States, as it will guard that young and prosperous Republic from the necessity of a fleet and all its tyrannous complication; hence I have taken these precautions to secure it to my country, lest any accident should happen to me in my present enterprise, to introduce a new mode of destroying fleets with effect, which, if successful, will never stop till the ocean is swept clean and commerce enjoy her right, navigation without control or impediment."

Among family papers are discovered two, which seem to bear witness to another result close following the invention of the steamboat.

Robert Fulton opened new paths for our nation where her footsteps were not known. In an address on the opening of the Erie Canal, on Independence Day, 1826, the Mayor of New York, said, "The completion of the Erie Canal by which the waters of the western lakes were united with the Atlantic, was an event of deep interest to the country at large and fraught with incalculable advantage to the State and City of New York. Few individuals in our country have possessed stronger claims upon its gratitude than Robert Fulton. The application of the power of steam for purposes of navigation has conduced so largely to the comfort and convenience of the civilized world as to form a new era in its history. The obstacles which time and space formerly interposed to the intercourse of mankind, and the uncertainty of the winds and tides has been rendered subservient to the magic influence of this powerful agent. For the benefits resulting from this momentous discovery the United States are indebted to the talents and perseverance of Robert Fulton, and for this his country delights to honor his memory."

It is a voice from the past, a tribute of old days; yet in the development which these 75 years have added we rejoice to echo them; for the East and the West are indeed united; the waters of the canal have borne their thousands of burdens, and the pathway for ships has become a royal highway whereon may travel the merchandise of our far fertile fields. This tribute was uttered 11 years after the death of Robert Fulton. To-day, 75 years later, another tribute is substantially reared by the American Society of Mechanical Engineers, Fulton's fellow-workers, who have carried on to this later day perfection the first efforts of that early day of promise.

The other paper of which I spoke, was also of deep significance, it illustrated the recognition of a city of the South. In 1883, the City of Charlestown, in her Bi-Centennial year, placed a bust of Robert Fulton in the Council Chamber, and Mr. Courtney, the Mayor, wrote to Mr. Fulton's daughter, expressing "his trust that this little act of comity may draw together in closer bonds the people of New York and South Carolina for centuries to come," and he adds, "May the union of the States be perpetual."

Beneath the inscription upon that bust are these potent words: "The City of Charlestown caused this bust to be erected as a Memorial to Robert Fulton's worth, and of his service in closely connecting her harbor with others of the world, and in her Bi-Centennial year the Hon. William A. Courtney, City Mayor, erects it in her Council Chamber to perpetuate his great achievement." These quoted words have value as a prophetic utterance that the power which Robert Fulton released and put in force has had important influence in the development of that close fellowship which, in the eyes of nations, characterizes the strength of our beloved country. East and West, North and South, we touch the ends of our ocean-bound continent and find existant harmony, a concord of brotherly peace and good will. Every national influence which strengthens these holy ties is to be revered, maintained and cherished, and for this cause I am privileged to-day to speak these words to you, in the shadow of old Trinity where beneath the perpetual benediction of its cross-topped spire Robert Fulton has slept these many years.

On the 25th of February, 1815, at 4 o'clock in the afternoon, the last sad offices for Robert Fulton were said upon this holy ground, when by all the officers of the National and State governments then in the city, by the magistracy, the Common Council, a number of societies, and a great gathering of citizens, the mortal body of this immortal man was laid to rest. From the time the procession began to move from his residence, No. 1 State Street, till it arrived at Trinity Church minute guns were fired from the steam frigate and the West Battery, and the flags of the vessels in the harbor were at half-mast.

Perhaps I can give no better words here than those written at the time of his death by the editor of the "Columbia," and published with black edged border. He says, in part, "This day the mortal remains of Robert Fulton are committed to the ground, consecrated by the tears of a bereaved community, who can never cease to deplore his loss, while they recollect his virtues and his genius, and enjoy the fruits of his talents and labors. As a scholar, a patriot, a friend and an ornament of the arts and sciences, a mechanician and public benefactor and worthy citizen, we can scarcely suppose that so deep and irreparable a chasm in society could be made in this extensive country during the infancy of our manufacturing efforts and handicraft improvements, by the loss of any other man of his professional cast in the nation."

These words were warm from hearts, alive with the loss of that by-gone day: yet they need not have been wholly sad, for thank God, "the good man does lives after him." Robert Fulton was indeed asleep, yet his invention, vigorous in its first infancy through his self-denial, flourished and lived with ever growing strength which is now finding its full development in the maritime fleets and world-famed Navy of our land. Look forth to-day upon the American waters; behold the small one hath become a thousand! And Fulton is to-day, in our thought because he dared to build that small one, because he hopefully looked forward to this future, because God gave him the mission and courage of a prophet. In 1845, Justin E. Moore, a poet, wrote these lines upon Fulton:

> "Oh, who like thee a monument shall claim,
> Walker of seas, of ocean floods sublime.
> Thine hast thou reared. Behold,
> Sun ne'er upon it sets where rolls the deep,
> Seas, oceans, lakes, streams, rivers, swift or bold;
> Towns, cities, villages in arctic cold,
> Or torrid zone, in east or far off west,
> On hill, or mountain, prairie, desert, wold,
> *There* is thy monument, that rich bequest
> Which myriads and myriads have blest!"

Each steamboat is indeed his monument. Yet to-day we rejoice that another permanent token near his resting-place has been reared by the American Society of Mechanical Engineers, and we meet together for its dedication. I have said that the last sad offices for him were read in this place. It is fitting that to-day we unite in these glad offices, which testify to the world an appreciation of his enduring worth. As pilgrims yet upon our way we come to rejoice for the triumph he won, and for the victory of the long ago. So shall we be stronger for our own waiting work which God intends us to do; so shall we win courage for our cruise on the yet unknown, with His hand on the helm to guide us.

No. 1006.

MEMORIAL NOTICES OF MEMBERS DECEASED DURING THE YEAR.

JOHN M. BOGLE.

Mr. Bogle was born in Knightsville, Rhode Island, in 1849. After moving to Fall River, Massachusetts, at an early age, he became a bookkeeper in one of the machine shops of the city; but the shop was more attractive than the office, and he soon forsook the latter to learn the machinist's trade, at which he worked in various shops until 1869, when he entered the employ of the Gorham Manufacturing Company, with which firm he stayed until his death. He began as toolmaker, but advanced rapidly to the position of Master Mechanic, which he held for twenty-five years. In this position he designed many special machines for the manufacture of silverware, and had entire charge of the machinery and plant, which stands as a monument to his life's work.

His death occurred unexpectedly from heart disease on March 7, 1901, while fixing a slight derangement to an automobile in which he was riding. He became a member of the Society in 1891.

THOMAS J. BORDEN.

Mr. Borden was born in Fall River, Massachusetts, March 1, 1832. At the age of sixteen he became a clerk in the Fall River Iron Works Company's office, where his father was Treasurer and active manager. He remained there for one year, and then went to the Lawrence Scientific School of Harvard, where he studied engineering and chemistry for two years; he then returned for two years to the office of the Fall River Iron Works. At the age of twenty-one he was appointed Agent and Manager of the Bay State Print Works, commonly known as the Globe Print Works, which about 1857 consolidated with the American Printing Company. In 1860 he was appointed Treasurer of the

Troy Mills, and after ten months succeeded in increasing the productive capacity fourfold, and during the sixteen years while he remained in charge, the value of the plant was increased in the same proportion. In 1868, when the Mechanics Mill was organized, he was made President and Agent, and the plans were drawn under his direction. In 1871 he organized the Richard Borden Mills, and planned Mill No. 1, in which he incorporated a system of perforated piping for the prevention of fire, this being the first system of the kind ever invented, and which has been developed into the automatic sprinkling system of the present time.

Colonel Borden remained as active manager of these three corporations up to 1876, when he retired to take charge of the American Printing Company. In 1863 he was commissioned as Lieutenant in the Fall River Light Infantry Company; in 1874 as Lieutenant in the Fifth Unattached Company; in the same year Captain of Company K, Third Regiment; Lieutenant-Colonel of same regiment in 1876; Colonel, 1868–71, when he resigned. He remained with the American Printing Company until the middle of the '80's, at which time he retired and became President and Treasurer of the Fall River Manufacturers' Mutual Insurance Company, and subsequently of three Rhode Island companies. In this field he became recognized among manufacturers as an authority on practical insurance management.

Colonel Borden, after a lingering illness, died in Providence on November 22, 1902.

WILLIAM D. CADWELL.

One of the most prominent cotton mill agents of New England, Mr. Cadwell gained his experience entirely in the mill, and was therefore in distinct sympathy with the employees in the large mills of which he had control. He was in charge for many years of the Jackson Manufacturing Company and the Nashua Manufacturing Company Mills, Nashua, New Hampshire, and it was only in 1900 that he left the former concern on account of the pressure of business. Mr. Cadwell was born in Montpelier, Vermont, October 16, 1834. He early went to Lowell, Massachusetts, and was employed in the Merrimac Cotton Mills until 1866, when he removed to Nashua to take a position as Master Mechanic in the National Company's Cotton

Mills. Two years later he was made Superintendent, and in 1871 Agent of the Jackson Mills, which position he held until 1900. In 1891 he became Agent of the Nashua Manufacturing Company also, and held this position until the time of his death. He was also Treasurer of the Nashua Gas Company from 1874 up to the time of its consolidation with the Nashua Light, Heat and Power Company.

Mr. Cadwell was prominent in Masonic circles, being a member of various important Lodges and Rites. He was President of the Masonic Building Association, member of the Currier Building Association, Director of the Pennichuck Water Company, Director of the Nashua Board of Trade, and of the Indian Head National Bank.

Mr. Cadwell had long been in failing health, although he was not seriously ill until within a few days of his death, which occurred October 10, 1902, of heart disease. He became a member of the Society in 1889.

JOSEPH CAVANAGH.

Mr. Cavanagh, in his early days, served his apprenticeship in mechanical engineering, and at the breaking out of the war enlisted as a bugler in the cavalry arm of the service, where he served for two years, being twice wounded. Upon his recovery he was honorably discharged, and enlisted in the navy, where he served as assistant engineer. At the close of the war he went to San Francisco, where he worked in installing the first cable road ever built; the actual construction of the first grip which was made being performed by him. He next entered the merchant marine service as engineer, and served for a number of years on the Pacific Mail Line, both on the Pacific and Atlantic steamers of that company. Later he located at Corpus Christi, Texas, where he established and managed the first artificial ice plant installed in that section. Incidentally he became the Superintendent of a group of mines in northern Mexico, which he managed with signal success. In 1885 he went to Philadelphia and entered the employ of the firm of Burr & Dodge, the predecessors of the Link Belt Engineering Company, the rapid development of which business was in a large measure due to his industry, mechanical knowledge and insight. He died after a two years' illness, on the 1st of July, 1902. He was elected a member of the Society in 1886.

ALFRED CHRISTIANSEN.

Mr. Christiansen was born in Christiania, Norway, July 10, 1856. He received a common-school education, and at the age of fourteen he went to sea, like most of the boys of his native country; his first voyage was to Scotland, and after his return the following winter, he studied navigation. After completing his studies he again went to sea; this time he visited the Western Continent. He experienced many hardships, and his ambition arose for something better and higher. After his return to Norway, he pledged his future life to engineering.

He wanted to go through all branches, and, starting as a blacksmith's helper, he went through the boiler shops, pattern shops, foundry and machine shops. In this capacity he had to work from six in the morning until six in the evening, and had over seven miles to walk both to and from work. After working-hours he attended evening school, where he studied until ten o'clock every night.

In 1875 he was able to take the entrance examination at the Technical School at Christiania, which he took with great honors. In 1879 he graduated at the head of his class.

In 1880 he came to the United States, landing in Philadelphia, where he became an employee of the Baldwin Locomotive Company, and afterwards of the William Sellers Machine Company, as a practical machinist. Later he went to Providence, where he worked at Brown & Sharpe's. Next he went to the Hinckley Locomotive Company, in Boston, where he began as machinist and left as master mechanic. In 1883 he went to the Watertown Arsenal Ordnance Department, United States Army, Watertown, Massachusetts, as a draughtsman, and was subsequently ordered to Watervliet Arsenal, where, after the completion of the gun factory, he became master mechanic, and remained in that capacity until his death, which occurred the 16th of January, 1903, caused by hemorrhage of the brain.

His last work was the completion of the largest coast-defence gun in the world. He became a member of the Society in 1889.

EDWARD A. DARLING.

Mr. Darling was born on Jersey City Heights on August 28th, 1865. He inherited on his mother's side a decided taste toward marine engineering and naval architecture, and from his father's side the training of the Scotch linen manufacturer. His father was a Dumfermline man in the heart of the linen district of Scotland.

Mr. Darling went to school in Walnut Hills, Cincinnati, and in the public schools of New York City, to which his parents moved. He entered a large wholesale tea house, but after two years of commercial experience he decided that mechanical work was his love, and he became an apprentice in the Delamater Iron Works, at the foot of West Thirteenth Street, New York City. Two years later he was made assistant tool maker with the Marvin Safe Works, with whom he remained until the autumn of 1886 when he entered Cornell University, taking a special course of two years. In 1888, after leaving Cornell, he accepted a position with the New Jersey Steel and Iron Works, and later transferred to the Campbell Printing Press Company, at Taunton, Mass.

On the withdrawal of Mr. H. F. J. Porter from the position of Chief Engineer of Columbia University, in 1891, and the creation of the position of Superintendent of Buildings and Grounds, of the University, on the accession of President Seth Low, Mr. Darling became the first incumbent of that position. This put him in charge of the systems of heating, ventilation and electric lighting of the University, at its old site at Forty-ninth Street and Madison Avenue. He had much to do with the installation of the mechanical plant in the new buildings of the College of Physicians and Surgeons, erected by the Vanderbilt family in 1893, and was the first to introduce the practice of mechanical refrigeration for the conduct of the work in practical anatomy in such an institution.

When in 1895–97 Columbia University faced the problem of removal from its restricted and inadequate site on 49th Street to its more satisfactory location on 116th Street and Broadway, the problem of designing the power-house of the University was placed in Mr. Darling's hands. It was proposed to heat the entire group of University buildings from a central power plant, and to furnish light and the power for ventilation purposes, electrically, from generators in connection with that central station. With the help of Mr. Frank J. Creelman the plans for this important power house were prepared by Mr. Darling, and executed in satisfactory shape, when the University was ready to occupy its buildings. A description of this plant was given in the *Transactions*, Vol. XXII. He had, moreover, the very difficult problem to face of removing the very elaborate and expensive collections of the Departments of Science of the University and installing them in their new home, and his services in carrying out this exacting requirement were most heartily appreciated.

In 1899 an opportunity came to Mr. Darling through his connection with the Society of Mechanical Engineers, which he had joined, to take a position of responsibility at Mr. Edison's plant for the manufacture of cement. The experience which he had had in the building of the Columbia plant on the large scale was very serviceable to him in this larger opportunity, and he at once took hold of the problem which was set before him. He met with great success, and was fully supported in his views by those representing Mr. Edison, so that presently he transferred his residence from the Oranges to Stewartsville, N. J. It was in connection with a most unfortunate combination of circumstances at the Stewartsville plant that Mr. Darling lost his life, March 16, 1903. The coal for a part of the plant was carried by a long conveyor to the point where it was to be used. A fire from spontaneous combustion in the pocket had attracted the attention of those in charge, and they gathered that the extinction had been complete after all outward signs of the fire had disappeared. But a glowing mass of coal fell into the conveyor and was carried unnoticed into the pulverizing room, where it set fire to the atmosphere of pulverized fuel, causing an explosion and a flame, which in its outrush from the building caught Mr. Darling in an open doorway, and produced burns from whose severity he was compelled to succumb.

It was a dramatic element in his life that he had been permitted to see the completion of his work at Stewartsville and the satisfactory operation of his designs before the call came to lay the work down. He became a member of the Society in June, 1891.

GEORGE R. FULTON.

Mr. Fulton was born in Pittsburgh, Pennsylvania, August 24, 1853. He enjoyed only a common-school education, and at the age of nineteen he entered the employ of the Pennsylvania Railroad Company as fireman.

In the fall of 1876 he made a change in his vocation, and became interested in the grocery business, which having failed to meet his expectations, he returned to mechanical pursuits in 1879, entering the employ of the Pittsburgh and Lake Erie Railroad Company as fireman, and after three months' service was advanced to the position of locomotive engineer in the passenger service.

In 1886 he entered the employ of the Westinghouse Electric and Manufacturing Company. He came to New York in 1889, and associated himself with the Mount Morris Electric Light Company, serving in the capacity of Superintendent until 1898, when he became connected with the J. G. White Company, and was placed in charge of the operating of the Gold and William Street stations of the New York Heat, Light and Power Company.

In the changes which took place in the electric-light situation in New York City in 1899, culminating in the organization of The New York Edison Company, Mr. Fulton's experience as an operating engineer and his excellent judgment in the handling of men were recognized in his appointment as Chief Engineer, which position he occupied until his death, December 4, 1902.

Mr. Fulton was a member of the Brotherhood of Locomotive Engineers, Division 148, and he became a member of the American Society of Mechanical Engineers in 1899.

WILLIAM GARRETT.

Mr. Garrett, inventor of the rod-rolling mill bearing his name, was born in Blain, Monmouthshire, Wales, May 25, 1843. At the age of eleven he started work in a rolling mill at Coatbridge, Scotland, where he rose rapidly, and at sixteen was in charge of a mill. He came to this country about 1868, and was for several years in the employ of the Cleveland Rolling Mill Company as Foreman and Assistant Superintendent. Later he became Superintendent of the rod mill constructed by the American Wire Company at Cleveland, and later became head of the Garrett-Cromwell Engineering Company. He designed and superintended the erection of mills in various localities. At one of the late meetings of the Iron and Steel Institute he read an important paper on "Rolling-Mill Practice."

His death occurred at Mount Clemens, Michigan, July 16, 1903. He became a member of the Society in 1888.

EDWARD GRAFSTROM.

Mr. Grafstrom was a native of Sweden, having been born at Motala on the 19th of September, 1862. He received his degree of Mechanical Engineer from the Boras Technical College in 1882, and came to America in September of that year, when he immediately became connected with the Pennsylvania Railroad in their Altoona shops. He was later sent to Columbus, Ohio, where he became Chief Draughtsman for the company. After seventeen years' service in the Pennsylvania Railroad he accepted the position of Mechanical Engineer of the Illinois Central Railroad, which place he soon left to take the same position with the Atchison, Topeka & Santa Fé system. He was just entering into the work of reorganization of mechanical stokers of that system, when his life was suddenly terminated during his heroic efforts in rescuing victims of the recent flood at Topeka, Kansas. At his suggestion and under his supervision, a small side-wheel steamer was hurriedly built in the Santa Fé shops. In charge of this boat and with a crew of seven men, he carried supplies to many sufferers, and brought back numbers of survivors. On the last return trip, on the night of Tuesday, June 2d, the boat struck an especially strong whirl of water, and for a moment could not be controlled, and at the same instant it struck a submerged tree and was upset. Six of the seven members of the crew escaped by clinging to tree-tops, but Mr. Grafstrom, though a powerful swimmer, was unable to make his escape and was lost.

He was elected a member of the Society in 1899.

WILLIAM HARKNESS.

Mr. Harkness was born at Ecclefechan, Scotland, December 17, 1837. He came to New York with his parents in 1839. He was educated at the Chelsea Collegiate Institute in New York, private schools at Fishkill Landing and Newburg, Lafayette College, Pennsylvania, and Rochester University, where he graduated in 1858, and from that University received the degree of A.M. in 1861, and that of LL.D. in 1874. He was a reporter in the New York legislature in 1858, and in the Pennsylvania Senate in 1860. He studied medicine and graduated from the New York Homeopathic Medical College, receiving the degree of M.D. in 1862; during that year he was appointed an Aide in the United States Naval Observatory at Washington, and in 1863 was appointed Professor of Mathematics in the United States Navy with the rank of Lieutenant Commander. For eight months he was attached to the United States Monitor *Monadnock* to observe the behavior of her compasses under the influence of heavy iron armor. His report on this work, together with observations and discussions of results, was published by the Smithsonian Institution in 1871. For one year, ending October, 1867, he was attached to the Hydrographic Office at Washington, and for the seven months following, the Naval Observatory. He made observations of several eclipses, and discovered the coronal line K 1,474, well known to astronomers; he observed the transit of Mercury in 1878. In 1871 he was appointed one of the original members of the Transit of Venus Committee. Soon after the second transit of Venus in 1872 he was given charge of the reductions of all the observations made by the American parties, and in 1889 made a report to the Secretary of the Navy, giving a brief statement of the result derived from the photographs made. In 1892 he was appointed Chief Astronomical Assistant to the Superintendent of the Naval Observatory, and in 1894 was appointed Astronomical Director of the Observatory with general supervision of all astronomical work. In 1897 he was appointed Director of the American Ephemeris and Nautical Almanac, and he retained both of these offices until his retirement for age, in 1899. During his life he published many scientific papers, and was a member of several scientific societies. He was twice Vice-President and once President of the American Association for the Advancement of Science.

At the time of his retirement he found that his health was quite seriously impaired, and as he was unable to take up any scientific work, he retired to his home in Jersey City. His death occurred on the afternoon of February 28, 1903. He became a member of the Society in 1891, and was a Life Member.

DAVID P. JONES.

Mr. Jones was born in Philadelphia, March 15, 1840. Little can be learned in regard to his early life and education, but in 1858 and 1859 he was appointed one of the two principal examiners of the Utah Public Survey. He entered the United States

Navy in 1862 as an Assistant Engineer, and after passing through the various grades finally became Chief Engineer in January, 1889.

In June, 1892, he retired for physical disability.

He was a very able draughtsman and designer, and was several times assigned to duty in the Bureau of Steam Engineering. Perhaps his most important effort was in the organization and development of the four-year course for Cadet Engineers at the Naval Academy. The first class under this course entered in 1874, and Mr. Jones was ordered to the Academy as Instructor, where he was on duty for five years. After his retirement he practised consulting engineering in Chicago and Pittsburgh, and at the latter place was assigned to duty as Chief Steel Inspector during the war with Spain. His death occurred on January 30, 1903. He became a member of the Society in 1881.

JOHN S. KLEIN.

Mr. Klein was born in Nassau, Germany, in April, 1849, and at a very early age came to this country with his parents and located in Buffalo, where at the age of sixteen he was apprenticed as machinist in the shops of the New York Central Railroad. After completing his term as apprentice he worked for a short time in Buffalo, but soon went to assume a position which his brother had secured for him in the oil field, at Plumer; this was in 1868. A little later he went in the shops of Smith & Crumbie, at Rouseville, and a little later went to Bredinsburg, in a repair shop for oil-well machinery, and for a year or two had complete charge of the latter establishment. After one or two other changes he was placed in charge of a machine shop of the Vandergrift & Forman Co. at Petrolia. This concern moved to Oil City, where it developed into a very large establishment. He is credited with a number of patents, which include a pipe-line scraper, which was a device for removing the deposits of paraffine from the inside of pipe-lines, the same being propelled by the current of oil. Also a pump for raising water from natural gas-wells by means of the gas pressure from said wells; throttling governors for gas-engines; cut-off inlet valve for gas-engines; metallic packing for gas-engine piston-rods; oil burner, in which oil is sprayed by compressed air; water-cooled rods and pistons for gas-engines. All of the above-mentioned devices are in extensive use throughout the oil and gas fields. The position which he held at the time of his death was that of Superintendent of Machinery with the National Transit Company. He was attacked with typhoid malaria, and after an illness of six weeks died at his home in Oil City, July 16, 1903. He became a member of the Society in 1893.

GEORGE LEACH.

Mr. Leach, engineer and architect, was born at Naples, Maine, September 16, 1843. His early life after completing a common school education was spent in mill construction and equipment. Later he began the study of mechanical engineering and machinery design, and in that class of work was employed by various concerns, among which might be mentioned the Saco Water Power Machine Shop, Biddeford, Maine; the South Boston Iron Works; United States Navy Yard at Portsmouth, New Hampshire; Whitehead & Atherton Machine Co., Lowell, Massachusetts, and Brown & Sharpe Manufacturing Co., Providence. In 1891 he established his residence at Providence, Rhode Island, where he was engaged in the design and erection of new buildings for the Brown & Sharpe Manufacturing Co. and various other concerns. He died at his home in Providence on November 27, 1902.

Mr. Leach became a member of the Society March 15, 1901.

WILLIAM VAIL LIDGERWOOD.

Mr. Lidgerwood was born in Morristown, New Jersey, on August 10, 1863. His education was obtained at the best schools of his native town, and was supplemented by recitations to tutors while serving his apprenticeship in Brooklyn. He also obtained his education in part from one of the professors of the Glasgow University, in Scotland. His apprenticeship in Brooklyn was in his father's works, the Lidgerwood Manufacturing Company. He was there for four years and then spent two years in his uncle's shops in Scotland. For the twenty years previous to his death he acted as his uncle's sole representative in Brazil, and created while there a large works at San Paulo, employing about three hundred men. He was both a scientific and practical engineer. He died on June 2, 1902, at the residence of his uncle, Mr. VanVleck Lidgerwood, in London. He became a member of the Society in 1886.

JOHN P. McGUIRE.

Mr. McGuire was born in Buffalo, New York, November 17, 1856. While still very young he removed with his parents to Cleveland, Ohio, and for several years attended both public and parochial schools. In early manhood he entered the employ of the Variety Iron Works as a clerk, and from that position arose, step by step, to the position of General Superintendent, which position he held at the time of his death. He had been in ill-health for some time, and for the second time had gone to Colorado, where, after two months stay, he died on the 17th of April, 1903. He was a man of large social qualities, being prominently identified with many of the social and fraternal organizations of his city. He was elected a member of the Society in 1898.

GEORGE S. MORISON.

Mr. Morison was born on the 19th of December, 1842, at New Bedford, Massachusetts. Prepared for college at Exeter Academy and graduated from Harvard in 1863. Three years after this he graduated from Harvard Law School. His first work was a bridge across the Missouri at Kansas City in 1867, where he served as assistant to Octave Chanute; he remained in Kansas City until 1871 and then removed to Detroit, where he became Chief Engineer for the Detroit, Eel River & Illinois Railroad. From 1873 to November, 1875, he was Principal Assistant Engineer for the Erie Railroad, and during that time rebuilt the celebrated viaduct over the Genesee River at Portage, New York. For ten years, commencing with 1875, Mr. Morison was associated with the house of S. C. and G. C. Ward, American agents for Baring Brothers & Co., of London, and in their interest served as Director of the St. Louis, Iron Mountain & Southern Railroad, the Eastern Railroad of Massachusetts, the Maine Central Railroad, and the Ohio & Mississippi Railway. He was a member of the bridge construction firm of Morison, Fields & Co. from 1875 to 1889. In 1887 Mr. Morison removed to Chicago, where for two years he was associated in partnership with Elmer L. Corthell. In 1894 he was appointed by President Cleveland on the Board of Engineers to report on the greatest practicable length of span for a proposed Hudson River Bridge. In 1895 he served on the Board of Consulting Engineers appointed to report on New York Dock Department matters. In 1896 he was appointed by President Cleveland as one of the members of a board for locating a deep-water harbor in Southern California. His appointment to the Isthmian Canal Commission followed in 1898. Probably his greatest work as a bridge engineer was the bridge over the Mississippi, at Memphis, Tennessee, which has a single truss span of 790 reet, being surpassed only by two other bridges of the sort in the world, the Forth Bridge in Scotland and the Lansdowne Bridge at Sukkur, India. He was President of the Amarican Society of Civil Engineers in 1895. His death occurred in New York City after an illness of about six weeks, on the 1st of July, 1903. Mr. Morison was elected a member of the Society in 1890.

JAMES OSCAR NIXON.

Mr. Nixon was born on the 26th of March, 1879, at New Orleans, Louisiana. Graduated from Tulane University in that city in 1897. Took a post-graduate course in sugar chemistry, occupying at the same time the position of chemist on a large plantation. After leaving the University he spent a year at Wilmington, Delaware, as Manager for one of the branches of a large foundry. Three years previous to his death Mr. Nixon became connected with the Link Belt Engineering Company at Philadelphia, and was almost immediately assigned to the testing and mechanical development of the work of that company. He had a great deal to do with the development and introduction of the Renold silent chain gear, and in December, 1901, presented a paper before the Society entitled the "Silent Chain Gear." Early in December of 1902 he was stricken with typhoid fever, which culminated in his death on the night of December 27th.

Mr. Nixon became a Junior Member of the Society March 15, 1901.

IRVING M. SCOTT.

Mr. Scott was born at Hebron Mills, Baltimore County, Maryland, in 1837. He was early interested in machinery, and went to Baltimore to learn the machinist trade, where he soon became not only a machinist but an expert draftsman and engineer as well. When twenty-two years old he went to San Francisco in charge of a steam fire-engine, and obtained a position there in the Union Iron Works. He rose rapidly, and after obtaining an [illegible] November, [illegible] and was Vice-President in [illegible].

[illegible] SHAW

Mr. Shaw was born on the [illegible] of September, [illegible] in [illegible], Allegheny County, Pennsylvania. After [illegible] he took a [illegible] in [illegible]. He [illegible] the study of [illegible] engineering at the age of [illegible] with the [illegible] Company. Later he was employed as Engineer with the [illegible] & Laughlin Steel Co., and afterwards went to the [illegible] Mining Company of Allegheny, where he [illegible] the position of Chief Engineer for several years. For many [illegible] years he [illegible] Chief Engineer of the [illegible] Company of [illegible], Pennsylvania. At the time of his death he was employed as expert on boiler practice by the [illegible] Company. Mr. Shaw died suddenly, and he was buried in McKeesport cemetery. He was elected a member of the Society in [illegible].

JAMES SPIERS

Mr. Spiers, one of the founders of the shipbuilding industry on the Pacific coast, was a native of Scotland, having been born at Paisley, May 1, [illegible]. During a part of his youth he worked in a bookstore, but at an early age ran away to sea. The next thing heard of him he was working as an apprentice in a boiler shop in Scotland. In 1852 he went to California, where, after having gained some experience at mining, he entered the Golden State and Miners' Iron Works, of which concern in a short time Mr. Spiers became sole proprietor, and shortly afterwards consolidated with the Fulton Iron Works. The plant was destroyed twice by fire, and it was only after the third successive rebuilding that the business was incorporated under the title of the Fulton Shipbuilding and Engineering Works, which has now become one of the largest on the Pacific coast. He was President and active director of the concern until three years before his death, when ill-health forced his retirement from active work.

He had much to do with the work of creating the Lick School of Mechanical Arts. His library on technical and mechanical subjects was perhaps the most comprehensive in his state. His death occurred in San Francisco on August 13, 1902.

He was elected a member of the Society in 1884.

GEORGE W. WEEKS.

Mr. Weeks was born in Waltham, Massachusetts, February 23, 1838, and in 1849 moved with his parents to Clinton, where his father became Superintendent of the Boylston Mill, of the Lancaster Mills. At thirteen years of age the younger Weeks entered the mill, and rose successively to positions as Clerk, Paymaster, Superintendent and Agent, in which last position he remained for nineteen years, or until his retirement from active business life in 1896. It was during Mr. Weeks' administration that the corporation became the largest manufacturer of gingham in the world. Although Mr. Weeks was self-educated, he was not only an authority on textile matters—particularly the use of the microscope—but he had a speaking and reading knowledge of French, German and Spanish, and was a fine musician. He always took a lively interest in the affairs of the town in which he lived, being for years a Director of the Public Library, a Trustee of the National and Savings Bank, and Clerk of the parish for the Unitarian Church. He was also interested in professional societies, being a member and for some time an officer of the New England Cotton Manufacturers' Association and a member of the Boston Textile Club, Boston Athletic Association, the Algonquin Club and the Home Market Club.

After his resignation from the position as Agent, he travelled extensively both abroad and in the United States. Early in 1902 he was injured in a railroad accident while returning from the Pacific coast, and never fully recovered; his death occurred suddenly of heart disease on October 7, 1902. He joined the Society in August 10, 1881.

JEROME WHEELOCK.

Mr. Wheelock was born in 1835 at Grafton, Massachusetts, and received his training as an apprentice at the Taunton Locomotive Works, from which firm he went to the Washburn Iron Works at Worcester. While with the latter concern he invented the Wheelock Cylinder Steam Packing, which he began manufacturing in 1865, and which is still in use. In 1870 he opened his own shop, and during the twenty years following invented and perfected the valve mechanism which is the essential feature of the Wheelock steam-engine.

He was elected a member of the American Institute of Mining Engineers in 1882. His death occurred very suddenly in Worcester, Massachusetts, on February 26, 1902. His membership in this Society dates from the time of its organization.

INDEX TO VOLUME XXIV.

NOTE.

1. For authors of papers and for the names of debaters upon them SMALL CAPS are used.

2. *Italic type* is used for the full titles of papers. Cross references to the subject of a paper which may not be its exact title are in Roman type, as are the titles under the caption of the author's name.

3. The Society is not responsible as a body for the statements of fact or opinion in its papers and discussions.